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WAR DEPARTMENT

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TECHNICAL MANUAL

UTILITIES

TECHNICAL MANUAL No. 10-220

WAR DEPARTMENT,
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UTILITIES

Prepared under direction of
The Quartermaster General

245260°—40——1

PART I

ORGANIZATION AND OPERATION

CHAPTER 1

ADMINISTRATION

SECTION I

GENERAL

1. General.—The term "utilities" as used in this manual includes the functions and operations at posts, camps, and stations which pertain to the maintenance, alteration, and repair of buildings; the maintenance and operation of plants and systems for heating, refrigeration, generation of electric power, water purification, sewage disposal, fire protection; and the maintenance of roads, walks, and grounds.

2. Object.—The object of this manual is to furnish detailed information and instructions to officers and enlisted men engaged in utilities activities.

3. Scope.—This manual includes detailed information relating to the organization and operation of a typical utilities division of a post quartermaster's office, including a description of the various reports and estimates required by existing regulations; instructions for filling out the prescribed standard forms; and the methods by which maintenance, repairs, and alterations (including minor construction), and the operation of utilities are accomplished. It also includes certain technical information concerning the materials and methods commonly used in minor construction and in maintenance and repair work. In addition, there are included certain engineering and technical data useful in the operation of various utilities installations (see part II).

SECTION II

UTILITIES ADMINISTRATION

4. Statutory authority.—The Quartermaster General, under the authority of the Secretary of War, shall be charged with the * * * direction of all work pertaining to the * * *, maintenance, and repair of buildings, structures, and utilities other than fortifications connected with the Army; * * * with the operation of utilities; * * * *Provided further*, That utilities pertaining exclusively to any branch of the Army may be operated by such branches. *Sec. 9, act June 3, 1916 (39 Stat. 170), as amended by sec. 9, act June 4, 1920 (41 Stat. 766; 10 U. S. C. 72; M. L., 1939, sec. 66).*

5. Construction Division, Office of The Quartermaster General.—*a.* In order to carry out those duties as outlined by law, the Construction Division of The Quartermaster General's Office is divided into the following branches:

(1) Administration Branch.
(2) Liaison Branch.
(3) Funds and Estimates Branch.
(4) Constructing Branch—Fixed Fee.
(5) Constructing Branch—Lump Sum.
(6) Repairs and Utilities Branch.
(7) Real Estate Branch.
(8) Legal Branch.
(9) Procurement and Expediting Branch.
(10) Engineering Branch.
(11) Accounting and Auditing Branch.

b. Each branch is further divided into sections along functional lines as necessity dictates.

6. Mission of the quartermaster, post, camp, or station.—Circular 1-1, O. Q. M. G., states that "The general duties of The Quartermaster General," defined above, "are executed by the authorized Quartermaster Corps installations and agencies consisting of the Office of The Quartermaster General, which directs, controls, and coordinates all operations * * * post, camp, and station quarter-

masters who administer quartermaster affairs at posts, camps, and station * * *." AR 30-5 places the post quartermaster under the direct command of the station commander who through military channels is responsible to the War Department.

7. Organization of the office of the quartermaster.—*a.* The office of the post quartermaster is normally organized as follows:

(1) Administrative Division.
(2) Supply Division.
(3) Utilities Division.
(4) Transportation Division.

b. It should be noted that the Utilities Division instead of the Construction Division is maintained in the office of a station quartermaster. This is so because new construction of a major character is handled directly by The Quartermaster General through constructing quartermasters, and all real estate activities through real estate officers (Cir. 1-1, O. Q. M. G.); therefore, the remaining activities (maintenance and repair work, minor new construction work, and operation of utilities) are handled by the more appropriately named Utilities Division. The Utilities Division, in order to carry out its functions of maintenance and repair, minor new construction and alterations, and operations of utilities is divided on a functional basis into the—

(1) Administrative Branch.
(2) Control Branch.
(3) Maintenance and Repair Branch.
(4) Operations Branch.

c. Each branch is further divided into such sections as are necessitated by local conditions. (See par. 8.)

8. Organization of Utilities Division; illustrative example.—*a. General data.*—Ft. School, Pa., is an assumed post which houses the 1st Quartermaster Regiment and the Quartermaster School and Service Detachments. Other data are as follows:

Name of post	Ft. School, Pa.
Barracks	Bldgs. Nos. 1-10, incl.
Officers' quarters	Bldgs. Nos. 100-156, incl.
Noncommissioned officers' quarters	Bldgs. Nos. 200-262, incl.
Other buildings	Bldgs. Nos. 300-366, incl.
Utilities at post:	
Water supply	Furnished by post plant.
Gas	Furnished by private company.
Steam heat	Furnished by post plant.
Electric light and power	Furnished by private company to post substation.

Refrigeration	Furnished by post plant.
Laundry	Furnished by post plant.
Sewage	Furnished by post plant.
Railroad	Post owned and operated, 3 miles single track to A. B. C. railroad.
Target range	Located on Government reservation, 5 miles from Ft. School, Pa.
Other facilities	All necessary walks, roads, etc.
Military population	87 officers. 6 nurses. 4 warrant officers. 68 noncommissioned officers of first three grades. 1,034 enlisted men.
Total	1,199
Civilian population (members of families)	650
Total population	1,849
Total animals	38 riding horses.
Total hospital beds	40

b. Organization, Utilities Division.—(1) The organization of the Utilities Division for Fort School, Pa., as shown in chart A, is considered adequate for a post of this size and type. Each branch has been given a designating letter and each section a designating number. In later references to this chart, branches and sections will be referred to by designating letters and numbers rather than by titles. For instance, a reference to A-2 would mean the Work Order Section of the Administrative Branch of the Utilities Division, Office of the Post Quartermaster.

(2) An inspection of this chart reveals that no set-up has been provided for—

(*a*) Administration of personnel.

(*b*) Fiscal accounting.

(*c*) Purchase, storage, and issue of supplies.

ORGANIZATION—UTILITIES OFFICE

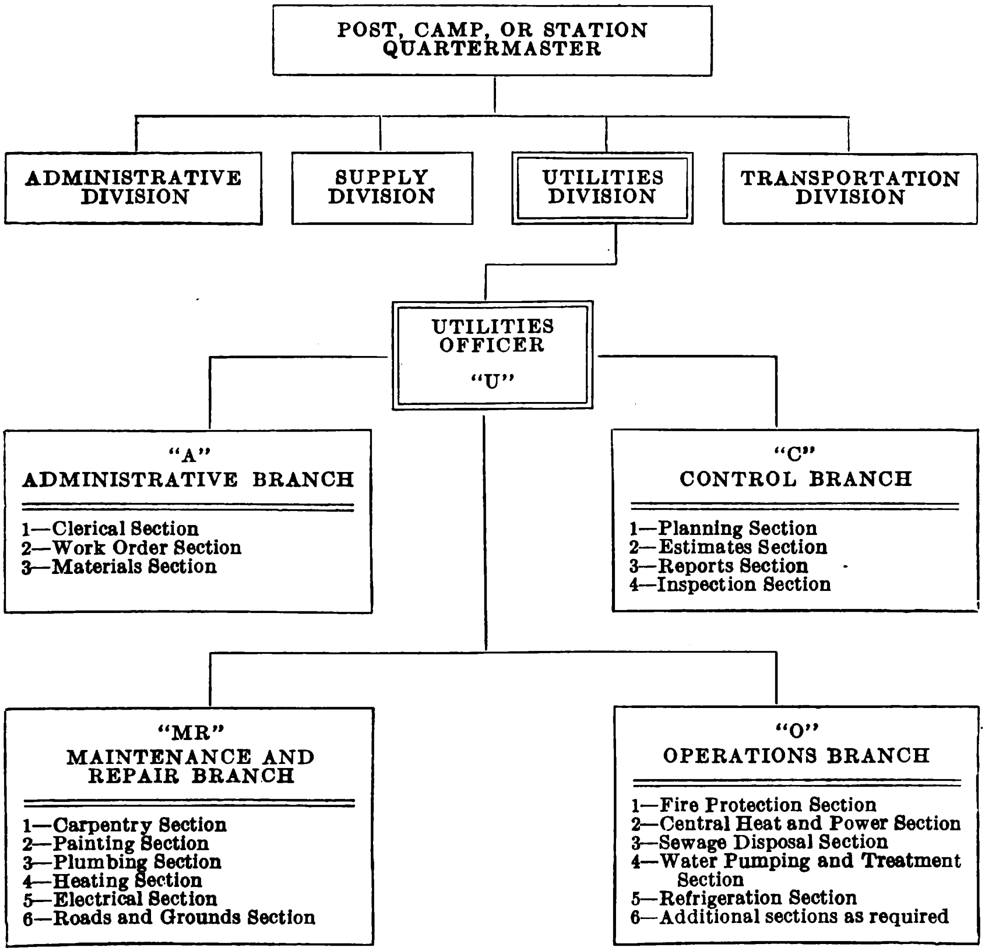

CHART A

Inasmuch as these three functions take place in the Supply Division and Transportation Division, as well as the Utilities Division, good organization to prevent duplication of effort requires allocation of similar functions to one division, which division serves other divisions insofar as that particular function is concerned. Hence, the administration of personnel and fiscal accounting are handled by the Administrative Division, and the purchase, storage, and issue of supplies, equipment, and tools, by the Supply Division.

(3) Although administration of personnel, fiscal accounting, purchase, storage, and issue of supplies are handled by other divisions of the office of the quartermaster, these subjects are discussed briefly in sections III, IV, and V.

9. Functions, Utilities Division.—*a. General.*—(1) In order to appreciate why the organization on a functional basis assumes the particular form shown on chart A, it is necessary to explain the functions of the various branches and sections. Again, it is emphasized that the Utilities Division is not a separate and independent organization at a post but that it is a part of the post quartermaster's organization. Hence, no functions are duplicated in the Utilities Division when similar functions are performed elsewhere in the post quartermaster's organization.

(2) The Utilities Division, when warranted by the volume of work, is headed by a commissioned officer, known as the "utilities officer" (designated on chart A as "U"), who is an assistant to the quartermaster. When no commissioned assistant is available, the quartermaster acts as his own utilities officer. It is the function of the utilities officer to supervise, control, coordinate, and administer all activities of the Utilities Division.

b. Administrative Branch.—The function of "A" is to supervise the activities of sections A–1 to A–3, inclusive.

(1) The Clerical Section (A–1) receives all mail referred to it from the Administrative Division of the quartermaster's office, routes it to the proper section for action, and maintains a follow-up to expedite the necessary reply. It either prepares the reply or a memorandum upon which the reply is to be based. No correspondence other than interoffice communications is filed in A–1, inasmuch as the Administrative Division, post quartermaster, has a Mail and Records Section for this purpose.

(*a*) A–1 is the custodian of the historical record of the post and files copies of all estimates, reports, etc., that pertain strictly to utilities activities.

(*b*) A–1 keeps the time cards of the personnel of the Utilities Division and transmits all required personnel reports to the Administrative Division, post quartermaster. The latter division prepares the pay rolls and keeps personnel records, etc.

(*c*) A–1 furnishes all typing service required by the Utilities Division and provides all office supplies and other office service required.

(*d*) A–1 handles such real estate matters as relate to the post in accordance with special instructions issued by the War Department.

(2) The Work Order Section (A-2) issues W. D., Q. M. C. Form No. 106 (Work Order), enters all costs of material and labor, and turns them over to the Control Branch. It also handles W. D., Q. M. C. Form No. 103 (Building Inspection Report) as soon as the responsible occupant has vacated the building and transmits it to the Control Branch. In other words, this section is concerned with maintenance and repair activities from the time the request for work originates until the work is completed, after which records covering each job are sent to the Control Branch for analysis and preparation of the required reports. This section (A-2) is always very busy with current daily operations and therefore is not concerned with activities which require planning and analysis.

(3) The Materials Section (A-3) keeps a current and accurate record of all materials (shop stock) and equipment on hand in the various shops of the Utilities Division. The actual procurement, storage, and issue of utilities supplies (including fuel) and equipment are handled by the Supply Division, post quartermaster's office, upon requisition by the Utilities Division. W. D., Q. M. C. Form No. 437 (Delivery Order and Receipt) is used for the purpose. Whenever stocks of utilities materials and supplies nced replenishment, A-3 prepares for the utilities officer's signature a memorandum to the Supply Division requesting that the necessary supplies be procured and stating what utilities funds are available for this purpose. Excepting equipment and materials actually on hand in the shops of the Utilities Division, all equipment and materials purchased from utilities funds are carried on the stock record cards of the property officer until issued. In general, all material left over from work orders is not sent back to the Supply Division but is picked up as shop stock, using W. D., Q. M. C. Form No. 446 (Credit Memorandum) for this purpose. A-3 also keeps a record of all equipment and tools issued to the utilities officer on memorandum receipt and secures memorandum receipts for all equipment, tools, etc., loaned to utilities personnel by the utilities officer.

c. Control Branch.—It is through this branch that the utilities officer controls and coordinates the operations of the Utilities Division, therefore the utilities officer himself exercises close supervision of its operations. The descriptive titles of sections C-1 to C-4 indicate the functions of each section.

(1) The Planning Section (C-1) studies all operation records of the various utilities plants (ice, water treatment, and sewage-disposal plants) and plans for such changes as will be conducive to more efficient operations; plans for the priority in the execution of major

repair projects within the limits of funds available; and does such other planning work as may be required.

(2) The Estimates Section (C-2) prepares estimates of cost for such changes as may be planned by C-1; it also prepares all annual and special estimates required by higher authority.

(3) The Reports Section (C-3) receives all performance records of the Maintenance and Repair Branch and the Operations Branch and prepares the reports required by higher authority.

(4) The Inspection Section (C-4) inspects all materials procured for the Utilities Division; it inspects each job when the work order is completed both as to the quality of the work performed and as to the amount of time taken to complete the job; and it inspects the functioning of the personnel at the various utility plants.

d. Maintenance and Repair Branch.—The functions of "MR" are to supervise, coordinate, and control the activities of sections MR-1 to MR-6, inclusive, from the date of issuance of a work order or the signing of a contract until work is completed. This branch performs the actual work required for minor construction and for maintenance and repairs upon buildings, other structures, and utilities. "MR" furnishes A-2 with a daily report of the time spent by each "MR" section upon each work order and notifies A-1 of the hours worked by the civilian personnel each day. "MR" notifies A-3 what supplies and materials are required for each work order, and A-2 then issues a warehouse order on the Supply Division for the necessary supplies and materials.

Sections MR-1 to MR-6 have descriptive titles that explain in general the functions that each performs. Section MR-5 performs all work in connection with the maintenance of the electrical distribution system as well as electrical installations in the buildings proper. If the post had its own electrical generating plant, it would be operated by a new "O" section rather than by MR-5. Section MR-3 maintains the gas-distribution system. Section MR-6 performs miscellaneous work not assigned to the other MR sections, such as cement work, masonry, etc. All miscellaneous hired labor and enlisted labor details are assigned to MR-6, and the labor pool furnishes laborers to the other sections as required. MR-6 makes all delivery of fuel, utilities materials, etc., and the Transportation Division furnishes the necessary trucks or wagons therefor. The number comprising the personnel of section MR-6 is subject to large fluctuations because the requirements for labor details differ at various seasons of the year.

e. Operations Branch.—The function of "O" is to supervise, coordinate, and control the activities of sections O-1 to O-6, inclusive. This

branch operates all utilities at the station. "O" makes a daily report to A-1 of the personnel present and absent from duty in each of the "O" sections and causes a daily operating log to be kept by these sections. Whenever fuel and operating supplies are required by any of the "O" sections, "O" secures the necessary warehouse orders for issue through A-3. "O" exercises general supervision over the operation of the individual heating plants.

(1) The Fire Protection Section (O-1) is supervised (when funds are available) by a civilian fire chief, who has had previous experience, preferably in some city fire department. Otherwise, a qualified enlisted man is trained by the utilities officer for this position. Under the fire chief there is an enlisted detachment which should be kept intact as a fire fighting organization for the longest possible periods of time. Changes when necessary should be made in such a way as to cause the minimum disturbance to the fire fighting team, and no changes should ever be made oftener than 30 days, except for demonstrated unfitness. One of the principal duties of the fire chief is to train his personnel in fire-fighting methods and in the use of fire-fighting equipment. Other duties consist of the inspections and tests of fire-fighting equipment, including the refilling of fire extinguishers in accordance with existing regulations. A continuous inspection should be made by O-1 to ascertain that no fire hazards exist. Proper data are kept to enable C-3 to accomplish W. D., Q. M. C. Form No. 118 (Analysis of Operation of Utility Plants).

(2) The Central Heat and Power Section (O-2) is charged with the operation of the plant, which includes the supervision of the personnel and the keeping of the daily operating log. O-2 must give timely notice to "O" when fuel and operating supplies will be required.

(3) The Sewage Disposal Section (O-3) is charged with the operation of the treatment of the raw sewage and its reduction to such a stable condition that it may be emptied into streams without danger of polluting them. Under O-3 are included the operation of the pumps for raising the sewage from one level to another; the operation of the septic tanks, filter beds, or other sewage disposal equipment; the testing of raw and treated sewage to determine the degree of purification that has been obtained, etc. Proper and adequate data are maintained to enable C-3 to accomplish Form No. 118. O-3 must give timely notice to "O" when fuel and operating supplies are required.

(4) The Water Pumping and Treatment Section (O-4) is charged with the operation of the reservoirs, water tanks, water pumps, the filter beds, and the testing of the water before and after treatment to

determine its purity. Adequate and proper records are maintained to enable C-3 to accomplish Form No. 118. O-4 gives timely notice to "O" when fuel and operating supplies are required.

(5) The Refrigeration Section (O-5) is charged with the operation of the refrigeration machines so as to maintain the required temperatures in the cold storage rooms and to provide the required temperatures for the production of ice. The Supply Division actually controls the storage and issue of ice and supplies in the cold storage room. Proper and adequate data are maintained to enable C-3 to accomplish Form No. 118. O-5 gives timely notice to "O" when fuel and operating supplies are required.

(6) Inasmuch as electricity and gas are purchased at this assumed station, no electric or gas generating sections are provided. If, at a later date, either of these utilities should be provided, then a section for their operation should be established.

SECTION III

PERSONNEL

10. General.—The personnel of the Utilities Division operates under the direct supervision of the utilities officer.

11. Civilian personnel.—*a.* The administration of civilian personnel is a function of the Administrative Division, office of the quartermaster, which operates in accordance with existing laws, instructions of the Civil Service Commission, applicable Army Regulations, and Circular 1-15, O. Q. M. G. However, any questions, such as employment, promotion, dismissal, disciplining, etc., of employees of the Utilities Division is submitted for the recommendation of the utilities officer before any action is taken.

b. The civilian personnel in the Utilities Division consists of—

(1) Overhead and operating employees considered as regular annual permanent personnel, funds for whom are specifically authorized and who are hereinafter referred to as project I employees.

(2) Temporary civilian personnel, other than those listed as permanent, funds for whom are authorized under repair projects.

12. Enlisted personnel.—From time to time, enlisted men are detailed to the Utilities Division from the quartermaster detachment or from other military units. These men work under the supervision of the utilities officer while so detailed, but all administrative records,

pay rolls, clothing records, etc., are maintained by the unit from which the enlisted men are detailed.

13. Personnel allotment, Utilities Division, Ft. School, Pa.—*a. General.*—The tabulation below shows the allotment of civilian and enlisted personnel which is considered adequate for the normal activities at Fort School, Pa. During the summer months, additional temporary civilian employees and enlisted personnel may be required for the preparation of summer training camps and similar work. In the tabulation the designation (I) represents a project I employee; (C) a civilian employee other than project I; (E) an enlisted man.

b. Administrative Branch.

1 principal clerk (I or E).
1 stenographer (C).
2 clerks (C or E).

c. Control Branch.

1 civil engineer, junior grade (I).
1 technical clerk (C or E).
1 clerk (C or E).

d. Maintenance and Repair Branch.

1 superintendent of repairs (I).
1 post carpenter (I) and 3 carpenters (C or E).
1 post painter (I) and 1 painter (C or E).
1 post plumber (I) and 1 plumber (C or E).
1 post steamfitter (C).
1 post electrician (I) and 1 electrician (C or E).
1 labor foreman (C) and 6 laborers (C or E).

e. Operations Branch.

1 superintendent of utilities (I).
1 fire chief (C) and 8 firemen (E).
2 plant operators (I) and 6 assistant operators (E).

f. Variations.—At smaller posts or stations the lack of adequate personnel may not permit the organization as above outlined, thus necessitating the consolidation of the duties of two or more of the positions. Likewise, at larger posts it may be necessary to provide additional personnel for various branches.

SECTION IV

FISCAL ACCOUNTING AND ESTIMATES

14. Fiscal accounting.—*a.* Fiscal accounting is a function of the Administrative Division, office of the quartermaster, which operates

in accordance with existing laws and regulations. However, the actual obligation of existing allotments of utilities funds and the preparation of estimates for utilities funds are functions of the Utilities Division, subject to the approval of the quartermaster. The Administrative Division maintains accounts of allotments of funds, supervises and coordinates estimates for funds required, and prepares all fiscal reports covering all funds allotted to the quartermaster.

b. Although the Administrative Division accounts for all utilities funds, nevertheless the utilities officer and his administrative personnel should possess a basic knowledge of Army fiscal accounting and of the laws, regulations, and instructions pertaining thereto. Such basic knowledge can be acquired by study of the following:

(1) Estimates for utilities funds.—Circular 1–2, O. Q. M. G.; AR 30–1435, 30–1760, and 210–70.

(2) Fiscal accounting.

(*a*) Fiscal procedure, general—AR 35–840 and Circular 1–2, O. Q. M. G.

(*b*) Accounting for public funds—AR 35–180 and Circular 1–2, O. Q. M. G.

(*c*) Deposit of funds received from sales—Sections IV and V, Circular 1–2, O. Q. M. G., and paragraphs 34–45, inclusive, Finance Circular B–7.

(*d*) Station list, posts, camps, and construction quartermasters—Finance Circulars C–1 and C–2.

(*e*) The War Department Procurement Code—Finance Circulars D–1 and D–4 of each current fiscal year.

Section V

UTILITIES SUPPLIES

15. General.—The purchase, storage, and issue of supplies is a function of the Supply Division. However, it is the duty of the Utilities Division to furnish definite specifications or other information as to the kind, quality, and amount of supplies desired and when they are needed for utilities maintenance, repairs, and operations. The Utilities Division provides the authorization for their issue. Operating supplies and supplies required in connection with work orders are withdrawn from the Supply Division on W. D., Q. M. C. Form No. 437 (Delivery Order and Receipt), and any un-

used balances are returned either to the warehouses or to the utilities shops on Form No. 4463 (Credit Memorandum).

16. Accountability and responsibility.—Accountability for utilities materials and supplies is carried in the Supply Division and must conform to laws and regulations pertaining thereto. Nevertheless, the utilities officer and his administrative personnel should possess a basic knowledge of property accountability and responsibility to insure that all operations and use of such material are in accordance with existing regulations. Such basic knowledge can be acquired by study of the following:

a. Property accountability and responsibility—AR 35-6520.

b. Requisitioning property—AR 35-6540 and Circular 1-6, O. Q. M. G.

c. Receipt, shipment, and issue of property—AR 35-6560.

d. Expendable property—AR 35-6620.

e. Contracts—Circular 1-3, O. Q. M. G.; AR 5-100, 5-140, 5-160, 5-200, 5-240, and 30-1415.

f. Procurement and distribution of supplies—Circular 1-4, O. Q. M. G.

CHAPTER 2

NEW CONSTRUCTION, ALTERATIONS, AND ADDITIONS

SECTION I

NEW CONSTRUCTION

17. General.—*a.* Army posts, camps, and stations consist of land, buildings, and other structures and systems such as water, sewer, electric and gas systems, roads, etc. Except for certain buildings and systems that may be acquired with the land, all posts are acquired and built up with funds appropriated by Congress for new construction. For instance, higher authority having decided that it is desirable to establish an Army post in a certain locality, The Quartermaster General, who is charged with the acquisition of real estate, makes an investigation of and estimate for acquiring a suitable site. The War Department after approval of the site includes in its estimates the funds necessary for such acquisition, and after the appropriation of funds is made by Congress the site is acquired.

b. The Quartermaster General, who is charged with construction, is then instructed by higher authority to prepare estimates of funds required to house the garrison, the size of which has been decided upon, and to provide the necessary utilities in connection therewith. After funds for this purpose have been appropriated by Congress, The Quartermaster General prepares the necessary plans and specifications and recommends the assignment of a constructing quartermaster to supervise execution of the work.

c. Upon completion of the construction project, the reservation, including the new buildings and utilities, and all contract drawings and specifications together with copies of a map of the reservation, are turned over to the commanding officer of the new station, and the troops move in.

d. The constructing quartermaster, upon the completion of any construction project executed under contract or by purchase of materials

and hire of labor, is required under AR 30-1435 to prepare a completion report which includes a detailed description of all types of buildings and utilities. A copy is furnished the post quartermaster. The completion report is used as the basis for preparation of the historical records of public buildings, structures, systems, and utilities referred to in section III.

18. Major new construction work.—Important new construction work is performed under the direct control of the Construction Division, Office of The Quartermaster General, through the direct representative in the field, namely, the "constructing quartermaster." However, in making small additions of one or more buildings to an existing station, the assignment of a constructing quartermaster may not be justified. In this event, the quartermaster or the utilities officer may in addition to his other duties be appointed constructing quartermaster or the work may be carried out by the utilities officer under the supervision of the post quartermaster.

19. Technical manual on construction.—It is not within the province of this manual to discuss in detail the subject of new construction nor the mission of the constructing quartermaster as he is not a part of the Utilities Division of the office of a post, camp, or station quartermaster. These subjects are treated in TM 10-230, Construction, which can be very useful to a post quartermaster or a utilities officer in the event he is also appointed a constructing quartermaster. The methods of carrying out new construction work are equally adaptable to minor construction and alterations and additions referred to in section II.

20. Approval.—*a.* In view of the importance of securing prior approval (where required) for any work, whether involving new construction, major alterations, or maintenance and repair (where the estimated cost exceeds $1,000), the following provisions are quoted from AR 30-1435:

5. APPROVAL.—*a. By the Secretary of War.*—(1) New construction or material alterations will not be made without the prior approval of the Secretary of War. "New construction" is defined to mean the erection or construction of any barracks, quarters, or other buildings, piers, wharves, plants, or systems. "Material alteration" is defined to mean additions to or alterations in public buildings, plants, or structures involving the new use of the buildings, conversion of barracks and quarters that changes their housing capacity; major changes in sewer, electric, gas, and steam systems involving technical operation; modification of plant capacity, including fuel-burning apparatus, and such changes as might weaken the structural strength of the building.

(2) No expenditure exceeding $5,000 in the case of corps areas or $1,000 in case of exempted stations, except as noted in *c* below, will be made upon any building, structure, system, or grounds at any one time without the prior approval of the Secretary of War.

b. By corps area commanders.—Corps area commanders are authorized to approve, from available funds, expenditures not exceeding $5,000 at any one time, on any building, structure, system, or grounds, except expenditures involving new construction or material alterations (as defined in *a*(1) above) which require the approval of the Secretary of War irrespective of amount.

c. By commanding generals of certain exempted stations.—The commandant, Army War College; the superintendent, United States Military Academy; the commandants, the Command and General Staff School, the Infantry School, the Cavalry School, and the Field Artillery School are authorized to approve, from available funds, expenditures not exceeding $5,000 at any one time on any building, structure, system, or grounds, except expenditures involving new construction or material alterations (as defined in *a*(1) above) which require the approval of the Secretary of War irrespective of amount.

d. Chiefs of arms and services are authorized to approve from available funds out of appropriations for which they are responsible expenditures not exceeding $5,000 at any one time on any building, structure, system, or grounds, except expenditures involving new construction or material alterations (as defined in *a*(1) above) which require the approval of the Secretary of War irrespective of amount.

e. By post commanders and commanders of exempted stations.—Post commanders and commanders of exempted stations other than those noted in *c* above are authorized to approve, from available funds, expenditures not exceeding $1,000 at any one time on any building, structure, system, or grounds.

f. Report will be made by letter to The Adjutant General on September 30, December 31, March 31, and June 30, of all expenditures in excess of $1,000 authorized under the provisions of *b*, *c*, and *d* above and of changes in systems not covered in *a*(1) above.

b. It should be noted in paragraph 5*e*, AR 30–1435, that post commanders are authorized to approve from available funds expenditures not exceeding $1,000 at any one time on any building, structure, system, or grounds provided the project does not involve new construction or material alterations. Thus, if it is desired to renovate a building by making repairs to heating, plumbing, and electric systems, and also to patch plaster and repaint it, at a total estimated cost of $2,000, it is first necessary to secure the approval of the corps area commander before undertaking the work. If the estimated cost of the project is $6,000, it is necessary to secure the approval of the Secretary of War. This type of project, involving renovation or repairs to a building or system, is covered in more detail in section II.

SECTION II

ALTERATIONS AND ADDITIONS

21. General.—Although the major portion of the utilities funds expended by the post quartermaster will be used for the maintenance of buildings, structures, systems, and grounds, and for operation of the utilities, nevertheless it is often possible to utilize a part of the utilities funds for alterations or additions to buildings and systems, such as the addition of a sleeping porch to a set of quarters or the construction of an additional sidewalk. Such alterations and additions effect a change in the physical condition of the post, and after completion the historical records must be changed accordingly.

22. Methods of accomplishment.—Alterations and additions to buildings, structures, and systems may be accomplished by either of two methods:

a. By contract.—(1) This method is used to advantage when the project is sufficiently large to interest bidders in competing for the work, or when the work to be done is of such special character that the necessary personnel is not available in the Utilities Division. If the work is to be done by contract, plans and specifications first must be prepared under the direction of the utilities officer.

(2) The contract is then awarded to the lowest responsible bidder. The details involving advertisement, award of contract, and supervision of work after award are similar to those involving contracts for new construction.

b. By purchase and hire.—This method is the one generally used for alterations, additions, and minor new construction work done by the Utilities Division. In this case the required construction materials are purchased by the Supply Division, turned over to the Utilities Division, and then incorporated in the work by the personnel of the Utilities Division, supplemented if necessary by additional temporary civilian labor or by troop labor.

23. Contract versus purchase and hire.—*a.* If work is done under a contract, the utilities officer's principal duties are the rigid inspection of the work in progress and the maintaining of reports necessary for use in making proper payments from time to time.

He is not concerned with the purchase of materials nor with the supervision of the workmen as all of these details are handled by the contractor.

b. Work done by contract is generally more expensive because the contract price includes the contractor's overhead expense and profit, while work done by the Utilities Division (the purchase and hire method) includes no profit, and the overhead expense is very largely carried by the existing personnel in the Utilities Division.

24. Construction materials and methods of construction, general.—Irrespective of whether the work of alterations, additions, or maintenance and repairs is done by contract or by purchase and hire, it is essential that the utilities officer and his technical personnel have a basic knowledge of the more commonly used construction materials and of the proper methods for their incorporation into the structure or system. Such knowledge can be had by a study of part II of this manual and of the reference books listed therein. Unusual problems always can be referred to the corps area quartermaster or to The Quartermaster General for instructions as to procedure.

25. Drawings and specifications.—*a. Drawings.*—In order to have any construction work properly performed, it is highly desirable to provide sketches and drawings so that the workmen will know exactly the requirements as to shape and size of the completed job.

b. Specifications.—It is impracticable to show on the drawings the kind, quality, color, etc., of the materials to be used or the methods by which they are to be incorporated into the work. It is therefore necessary to supplement the drawings by a written or printed set of instructions which are called the "specifications." These specifications are of three classes:

(1) Project specifications which are applicable only to the particular work under consideration.

(2) Federal standard stock specifications which cover various materials commonly used by all the departments and individual establishments of the Government. These specifications are referred to in the project specifications whenever they are applicable to the materials to be incorporated in the work. They are designated by certain symbols (such as SS-C-101 for cement-masonry) placed in the upper right corner of the first page. Section IV of the Federal Standard Stock Catalog gives a complete list of the specifications available.

(3) United States Army specifications which cover various materials for which no Federal specification has been prepared. These specifications are binding only upon the War Department and are

marked on the first page by "U. S. Army Specification" in the upper left corner and by certain numerals separated by a hyphen in the upper right corner, such as No. 83-6 (date) for plumbing fixtures.

c. Typical drawings.—The Quartermaster General has prepared many drawings and specifications for certain types of new construction work, and whenever the quartermaster or the utilities officer desires to undertake any minor new construction work or major alterations or additions he should secure from The Quartermaster General a copy of such drawings and specifications. This will be very useful as a guide in preparing drawings and specifications for the particular work in question.

26. Laying out construction work.—Before any construction work or alterations and additions are begun, it is necessary that certain points be established to show the proper location of the work, and that certain elevations also be established to show the relation of new work to existing work or to the ground. For this purpose many instruments are available such as the transit, level, level rod, steel tape, etc. It is not within the province of this manual to describe the use of the above instruments for laying out construction work, but a detailed description of their use can be found in any authoritative Civil Engineers' Pocket Book.

SECTION III

HISTORICAL RECORDS

27. General.—*a. Forms.*—AR 30-1770 requires that historical records for public buildings, structures, and systems be prepared on standard forms, and that when additions or alterations thereto are made such changes will, upon completion of the work, be reported for notation on the historical records. The forms used are—

	W. D., Q. M. C. Form No.
Electric Lighting and Power	90
Transformers	91
House Lighting and Watt-Hour Meters	92
Water Supply System and Water Pumping Plants	93
Sewerage Systems and Waste Disposal	94
Furniture, Refrigerators, and Lockers	107

	W. D., Q. M. C. Form No.
Boiler and Power Plants	109
Laundry Plant	110
Refrigerating Plant	113
Gas System	114
Central Heating Plants	115
Individual Heating Plants	116
Historical Record of Public Buildings	117

b. Sources of information.—The original historical record forms are made up from data included in the completion report prepared by the constructing quartermaster, supplemented when necessary by a physical inspection of the buildings, structures, and systems. Once completed, the historical records need not be changed unless alterations or additions to buildings, structures, and systems are made at a later date. Any such changes are found in the records of the Utilities Division (work orders and contracts), and this information can be abstracted and the original records changed accordingly. Further details as to these changes are found in AR 30-1475, 30-1505, 30-1515, 30-1670, 30-1675, 30-1680, 30-1685, 30-1690, 30-1710, 30-1715, 30-1770, and 30-1780.

28. Reports.—In addition to the historical record forms referred to above, the annual reports of equipment, capacity, and condition of buildings, systems, and utilities are shown on W. D., Q. M. C. Form No. 111 (Record of Equipment and Condition of Buildings) and on W. D., Q. M. C. Form No. 112 (Record of Equipment and Condition of Utilities) as of June 30 each year.

29. Preparation and distribution.—All historical record forms and Forms Nos. 111 and 112 are prepared and kept up to date by the Control Branch. For posts under the jurisdiction of a corps area commander the forms are prepared in triplicate. One copy is retained at the post and two copies forwarded to the corps area commander, of which one (the original) will be forwarded to The Quartermaster General. For independent posts or stations the forms are prepared in duplicate, one copy for retention at the post and the other for transmission to The Quartermaster General (AR 30-1770).

30. Specimen forms.—A specimen copy of each of the forms referred to herein is included in appendix I. Where necessary, detailed instructions for filling out the forms are included on the forms.

CHAPTER 3

MAINTENANCE AND REPAIRS, AND OPERATION OF UTILITIES, PLANTS, AND SYSTEMS

SECTION I

GENERAL

31. General.—Immediately after a new building, structure, or system is completed it begins to deteriorate, and funds are required for maintenance and repair of such installations in order that they may be kept in serviceable condition. It should be appreciated that funds expended for maintenance and repair do not necessarily increase the value of the buildings, plants, and systems. Thus, an exterior flight of wooden steps on a building might be replaced two or three times in a period of years, but the value of the building would not be increased. In commercial practice it is customary to allow a certain annual percentage for depreciation in value of the investment. In military service a record is kept for each building, structure, and system, showing the amount of funds expended annually for maintenance and repair work, and an annual estimate is also made of the replacement cost.

32. Funds.—At the beginning of each fiscal year funds for maintenance and repair, alterations and additions, and for the operation of utilities are made available to each post by The Quartermaster General. The allocation of funds within the limits of funds appropriated by Congress is based on the annual estimates submitted each year by all posts. (For preparation of annual estimates see section V.)

SECTION II

PLAN FOR EXPENDITURE OF FUNDS

33. General.—In connection with the maintenance and repair of buildings, structures, and systems, and the operation of utilities, the War Department has established certain policies as set forth in the following excerpts:

> Corps area and department commanders, by means of a board or other methods, will determine the relative requirements of all posts and activities within their corps areas. Upon notification of the amount of funds allocated to the corps area, corps area commanders, withholding a very small amount to meet emergencies, will allocate to posts and activities within their corps areas the amount each is to get for the entire fiscal year. * * *
>
> As soon as funds have been allotted to posts, the post commanders, by means of a board or other effective methods, will cause to be prepared a plan of funds so allocated. This plan will be forwarded to corps area or department commanders who, after approval, or approval as modified, will return it to the post commander. This plan will then be carried out by the post commander unless variation therefrom is approved by the corps area or department commander.
>
> The final responsibility for the expenditure of funds allotted for maintenance, upkeep, and repairs rests squarely upon commanders. Conservation and the proper maintenance of post buildings and utilities are serious functions of command and cannot be avoided or delegated to subordinates. In the future, the maintenance and repair of posts will be considered of equal weight with training in determining the efficiency of commanders. To this end, programs of maintenance, upkeep, and repair will be prepared as well as programs of training, in order that both objects may be accomplished through coordinated action.

34. Utilities plan.—Seldom will the amount of funds allotted to a station equal the amount requested in the annual estimate; therefore it is almost certain that some of the less important projects will have to be omitted from those contemplated. The question of which projects to omit is one for the commanding officer to decide, after which the post quartermaster upon consultation with his utilities officer makes up a utilities estimate and plan, showing the proposed method of expenditure of utilities funds for the coming fiscal year.

a. Estimate.—(1) In making the utilities estimate of the situation, consideration is given to the total amount of funds allotted to the post and, within this amount, reservations are set up for the following:

(*a*) Pay for project I permanent civilian employees.

(*b*) Contracts for nonpersonal services, such as purchase of electric current, water, gas, rental of camp sites, etc.

(*c*) For operating supplies for utilities plants and systems, such as power plant, refrigeration plant, water purification plant, etc.

(*d*) For a sufficient reserve to take care of ordinary maintenance

and repair activities, such as purchase of materials, equipment, and tools, and hire of temporary civilian labor. The required amount for this purpose can be estimated from similar expenditures of previous years.

(2) After setting up the above reservations, the remaining available funds may be used in the execution of maintenance and repair work of a more extensive character, the need for which was noted during the annual inspection of the post by the commanding officer as required by Army Regulations.

b. Plan.—After completion of the utilities estimate, the utilities officer under the supervision of the post quartermaster prepares the utilities plan of operations for the ensuing fiscal year. This plan is substantially as follows:

(1) Statement of available funds.

(2) Statement of reservations to be set up to take care of normal requirements for the station.

(3) Statement of other maintenance, repair, and alteration projects (estimated to exceed $1,000), arranged in order of priority, which are to be accomplished with the remainder of the funds. This priority list should be arranged to show the entire number of projects contemplated for completion during the fiscal year, but the recommendations should include only the projects for the first quarter of the year. However, in order to pass properly upon the quarterly plan, the commanding officer should have the entire list of projects available, as he may desire to make rearrangements and include some of the projects in the first quarter. Experience has shown that it is very difficult to make a plan that will hold for an entire fiscal year because the estimated costs of projects very seldom agree with the actual cost. Therefore, just before the end of each quarter, a new quarterly utilities plan is prepared for the succeeding quarter based upon the funds available at that time.

(4) Statement as to proper time for buying certain materials, such as fly screening, paint, etc., which fluctuate in price with seasonal demands.

(5) Statement of other factors that tend to provide for economical expenditure of funds, such as when additional temporary personnel shall be employed, etc.

(6) For individual projects involving expenditures of more than $1,000 for maintenance and repair and for all projects involving new construction or material alterations (ch. II), the plan should be accompanied by detailed estimates for each individual project on W. D., Q. M. C. Form No. 105 (Project Estimate).

35. Action by commanding officer.—*a.* Upon receipt from the post quartermaster of the utilities plan, the commanding officer inspects it, makes any changes that he considers necessary, and then submits it for the approval of the corps area commander.

b. The corps area commander makes any changes in the plan that he considers necessary. If the plan includes any individual projects involving new construction or major alterations, or any projects involving the expenditure of more than $5,000 for maintenance and repair, he detaches the individual estimates (Form No. 105) from the plan and forwards these individual estimates with his recommendations to the War Department. With an explanation of his action, the commanding general approves the plan and returns it to the post commander, who, in turn, returns it to the post quartermaster.

c. The post quartermaster then turns the plan over to the utilities officer, who uses it as a guide for the next fiscal year's activities. No changes may be made in the priorities established in the utilities plan without first obtaining the approval of the corps area commander.

Section III

MAINTENANCE AND REPAIRS

36. General.—Maintenance and repairs are usually accomplished by the permanent civilians and soldiers of the Utilities Division, augmented when necessary by the employment of temporary civilian personnel. However, in certain repair work to machinery or any major repairs or alterations, adequate personnel may not be available. In this event, a contract may be entered into with an outside firm after preparation of the necessary plans and specifications, advertisement, etc., as outlined in chapter II.

37. Requests for maintenance and repairs.—*a.* To avoid error and confusion, requests for repairs (except for emergencies) made by personnel residing on a post should be in writing and they are accomplished by—

(1) Entering the requests on the request book at post headquarters, or

(2) Where request book is not used, making requests on special forms prepared locally and made available in a convenient location at post headquarters and in the quartermaster's office.

(3) Communication to the commanding officer or to the quartermaster direct.

b. Requests to make emergency repairs, such as repair of leaks in water and gas lines, etc., should be telephoned during office hours direct to the Utilities Division. After office hours (nights, Sundays, and holidays), a central telephone should be used where some employee of the Utilities Division is on duty at all times, i. e., at a central heating plant, refrigeration plant, or some similar plant. All residents of the post should be informed, preferably by publication in the post telephone directory, of the telephone numbers to be called for emergency repairs.

c. The commanding officer, the quartermaster, the utilities officer, or the personnel of the Utilities Division initiate such other maintenance and repair work as may in their judgment be considered necessary, including special projects in the utilities plan.

38. Work order.—*a. General.*—All orders for repairs, alterations, and additions of any nature whatsoever are issued on Form No. 106. For emergency repairs, a confirming work order is issued. For projects involving a considerable expenditure of funds, the approval of the quartermaster and the commanding officer is first obtained before issuance of a work order. By this means, the commanding officer exercises control over the expenditure of utilities funds and at the same time relieves the post quartermaster of any embarrassment which he might feel in refusing to grant a request for needless expenditure of funds.

b. Illustrative example.—(1) Assume that the following entry has been made December 3, 1939, in the request book and has been approved by the commanding officer:

"Replace old tin-lined bathtub with enameled cast-iron bathtub, in second-story toilet of Quarters No. 132.

(Signed) M
1st Lt., Cav."

(2) Assume also that the last work order issued was No. 2541–40.

c. Processing of a work order.—(1) The work order clerk (A–2) in accordance with instructions from the utilities officer prepares

Form No. 106 in triplicate, making the following entries:
Work Order No. 2542-40.

NOTE.—The first four figures of the work order indicate that it is the 2542d order issued during the fiscal year 1940. The number of the year is indicated by the last two figures, i. e., -40.

Building No.	Perm. Off. Qrs. No. 132.
Requested by	1st Lt. M, Cavalry.
Date	December 4, 1939.
Nature of order	Replace present tin-lined bathtub with enameled cast-iron bathtub, type No. 66 R, complete.
Work assigned to	"MR"—G. R. Harrison.

The triplicate copy of the work order is given to the utilities foreman (MR), and the original and duplicate copies are retained by A-2.

(2) *Action by "MR".*—"MR" presents an outline of the work to Jones (MR-3), the post plumber; to Jackson (MR-1), the post carpenter; to Smith (MR-2), the post painter, and secures from them the list of materials that they require. "MR" examines the stock on hand (shop stock) and indicates to A-3 what materials are needed. After preparation of an order by A-3 on Form No. 437 (in duplicate) covering those supplies requested, the order is given by "MR" to the shop stock clerk for issuance. For the material not in shop stock, "MR" secures from A-3 another Form No. 437 (in duplicate) which he presents to the property officer. The property officer indicates which of the materials issued were purchased during the fiscal year 1940 and which were issued from stock on hand at the end of the fiscal year 1939. "MR" signs for the materials when received and leaves the original signed copy of Form No. 437 with the clerk in charge of the shop stock account and the clerk in charge of the stock record account, respectively. The duplicates are turned in together with the completed work order to A-2 on December 10, 1939. "MR" also notes thereon the amount of labor consumed on the work order. If any material is left over on this work order, it is returned to shop stock on Form No. 446, and the original Form No. 446 signed by the shop stock clerk is also turned in by "MR" with the completed work order.

(3) *Action by A-2.*—(*a*) The work order clerk extends the costs of labor as reported on "MR's" copy of the work order, posts to this copy the net amount of materials consumed as evidenced by the copies of Forms Nos. 437 and 446, and then completes the items on the face of the work order.

WAR DEPARTMENT
Q.M.C. Form 106 (old 509)
Revised July 2, 1934

WORK ORDER

MAINTENANCE OF UTILITIES

Order No. 2542-40 {Building / Utility} No. Perm. Off. Qrs. #132

Requested by Lt. "M", Cav. Date Dec. 4, 1939.

Date completed December 10, 1939

Inspected and found satisfactory.

(Signed) "M", 1st Lt., Cav.

Nature of Order

Replace existing tin-lined bathtub with an enameled cast-iron bathtub, type 66R.

Work assigned to

Mr. Harrison (MR)

Enlisted labor 24 hrs. @ .50 per hr.	$ 12	00
Civilian labor ... hrs. @ ... per hr.	5	90
Material { Purchased	61	52
Material { Stock on hand	2	70
Contracts		
Personnel, Project No. 1 ... hrs.	(No cost to be shown)	
Total cost	$ 82	12

Classification of repairs made:

Project No. 12 Approp. B&Q, A Designation Perm. Qtrs.

NUMBER OF UNITS	UNIT	UNIT COST
1	Bldg	$82.12

(FOR DETAILS OF WORK SEE OTHER SIDE)

U. S. GOVERNMENT PRINTING OFFICE: 1934

(b) A–2 then transfers the data on the triplicate copy of work order to the original and duplicate copies of the work order and sends these two latter numbers to C–3. The triplicate copy of the work order and supporting Forms Nos. 437 and 446 are filed in files of the Control Branch.

(4) *Action by C 3.*—C–3 files the original copy of the work order according to project number for use in the preparation of Form No.

Personnel Detail Cost

Post Plumber Jones (P 1)	10 hrs.		
Post Plumber Helper White (Temp. Civ.)	10 hrs.		
Post Carpenter Jackson (P 1)	6 hrs	@ $0.59	– $ 5.90
Post Painter Smith (P 1)	4 hrs.		
			$ 5.90
Enlisted Labor	24 hrs	@ $0.50	$12.00

Materials—Details

Materials Purchased in F.Y. 1940:			
1 Bathtub, type 66R	@	$52.00	– $52.00
10 Lin. ft. 3/4" brass pipe	@	.20	2.00
2 ea. 3/4" brass ells	@	.25	.50
60 Bd. ft. flooring, y.p., 2-1/2" face	@	.04	2.40
50 Lin. ft. shoe mold	@	.01	.50
0.5 Gal. shellac	@	2.40	1.20
1.5 Gal. paint, prepared	@	1.80	2.70
1.0 Lb. wax, floor	@	.22	.22
Total materials purchased			$61.52
From stock on hand:			
10 Lin. ft. 2" G.I. pipe	@	$ 0.20	$ 2.00
2 ea. 2" G.I. ells	@	.30	.60
2 Lbs. nails, assorted	@@	.05	.10
Total stock on hand			$ 2.70

Remarks

95 (sec. V); the duplicate copy is filed according to building number and at the end of the fiscal year is used in the preparation of Form No. 104 as hereinafter explained (sec. V).

39. Importance of work order.—The work order is a very important record in utilities administration for the following reasons:

a. It furnishes basic data for use in the preparation of the annual estimate and other reports required (sec. V).

b. It provides a means for the utilities officer to determine the labor efficiency of the employees and their economy in the use of materials.

c. A retained copy in the office of the utilities officer serves as a follow-up, enabling him to expedite the jobs that are making slow progress and to anticipate the need for employment of additional temporary civilian labor (sec. V).

SECTION IV

OPERATION OF PLANTS AND SYSTEMS

40. General.—In addition to funds required for new construction, alterations and additions, and maintenance and repairs at a post, funds are required for operation of utilities plants and systems, such as heating plants, refrigeration plants, gas systems, electric systems, water and sewerage systems, etc. Funds expended for operation of such plants and systems are for hire of labor, for purchase of fuel, light and power, for operating supplies, and for overhead personnel. Such expenditures do not increase the value of these plants and systems, nor do they include maintenance and repair funds to keep such plants and systems in serviceable condition, but the funds expended under operation do increase the usefulness of buildings and provide services such as heat, light and power, gas, fire protection, and similar services that, accordingly, increase the health and contentment of the personnel at the post. Hence, this class of expenditures, operation costs, requires certain forms for records, reports, and estimates (sec. V) in order that it may be determined whether the plants and systems are being economically operated.

41. Method of securing services.—The various utility services such as light and power, gas, water, etc., may be provided at a post—

a. By contracting for such services with commercial or municipal utility corporations, or

b. By constructing and operating such utilities plants at the post itself, in which case the expenses will consist of expenditures for the required operating personnel and for operating supplies required by each respective plant. It is impracticable in this manual to include all of the various operating supplies required in the operation of utilities plants and systems. However, the principal items are coal, gasoline, oils, greases, electric lamps, chemicals for water purification plant and for fire extinguishers, gage glasses, charts, etc.

42. Cost of operation.—The operation of any utility plant at a post, such as an electric generating plant, is not justified whenever electric current can be purchased (if available) at reasonable cost from a private or municipal plant. Therefore, a record should be kept of all operating costs and of the plant output in order to determine which method should be used to provide electric light and power service for the post. Even when no private corporation can furnish such service, it is necessary to keep such records to determine if the plant is being economically operated and, if not, what changes should be made to provide for more economical operation.

SECTION V

RECORDS, REPORTS, AND ESTIMATES

43. General.—*a.* In addition to the historical record forms referred to in chapter II, the following standard forms are used in keeping records and in making estimates and reports pertaining to utilities:

	W. D., Q. M. C. Form No.
Annual Report of Maintenance—Repair and Operation, Buildings and Utilities	95
Building Inspection Report	103
Annual Report of Construction and Repair	104
Project Estimate	105
Work Order	106
Annual, Heat, Light, and Power Distribution	108
Extract—Heat, Light, and Power Distribution	108a
Analysis of Operation of Utility Plants	118
Delivery Order and Receipt	437
Credit Memorandum	446

b. Detailed instructions pertaining to the preparation, use, and distribution of these forms are included in the paragraphs which follow, and a specimen copy of each form is included in appendix I.

44. Form No. 95.—*a.* Basic instructions pertaining to the preparation and submission of this form (also Form No. 105) are contained in AR 30-1760. In view of the importance of estimates for funds, the following provisions are quoted from AR 30-1760:

4. ESTIMATES.—*a. Annual.*—(1) *When and by whom prepared.*—As soon as practicable after the annual inspection required by paragraph 2*an*, AR 210-70, the post commander will require the quartermaster to prepare estimates on W. D., Q. M. C. Form No. 95 (Annual Report of Maintenance, Repair and Operation), pertaining to the maintenance, repair, and operation of buildings and utilities coming under the direction of The Quartermaster General.

(2) *Action at corps area headquarters.*—Corps area commanders will submit annually consolidated estimates on W. D., Q. M. C. Form No. 95, showing—

(*a*) The total amounts required under each appropriation, by projects, for the fiscal year beginning the 1st of the following July. The data in this estimate are used by the War Department in making allotments to corps areas.

(*b*) The total amounts required under each appropriation, by projects, for the fiscal year beginning the 1st of the next July succeeding the July mentioned in (*a*) above. The data in this estimate are used by the War Department in making requests to Congress for appropriations.

(3) *Exempted stations.*—Commanding officers of exempted stations will submit annually similar estimates on W. D., Q. M. C. Form No. 95.

(4) *Date of forwarding.*—The estimates required by (2) and (3) above will be forwarded in ample time to reach the office of The Quartermaster General not later than January 1 of each year.

(5) *Data required.*—These estimates will show—

(*a*) The specific amounts required under each of the following projects:

1. Fuel, light, and power.
2. Incandescent lamps.
3. Operating supplies.
4. Purchase of water.
5. Transportation of maintenance, repair, and operation materials.
6. Rentals.
7. Recruiting stations and lodging for recruits.
8. Regular overhead and operating personnel.
9. Maintenance, alteration, and repair of buildings, utilities, and systems.
10. Fire apparatus.
11. Refrigerators, wall lockers, and furniture.

(*b*) Amounts expended under each of the above projects during the preceding fiscal year.

(*c*) Amounts estimated to be spent under each of the above headings during the current fiscal year.

(*d*) Detailed explanation of all increases or decreases.

b. Individual projects.—(1) *When any, by whom prepared.*—After funds have been allotted to stations, post commanders will prepare estimates to be submitted on W. D., Q. M. C. Form No. 105 (Project Estimate), for all individual projects for expenditures for more than $1,000 and all new construction or material alterations as defined in paragraph 5*a*(1), AR 30-1435.

(2) *Date of forwarding.*—Post commanders will submit these estimates at such times as may be prescribed by corps area commanders. Commanding officers of exempted stations will forward their estimates for the first quarter as soon as practicable after the receipt by them of notification of allotments to their stations, and for succeeding quarters at such times as to permit action by the War Department prior to the beginning of the quarter in which it is expected to do the work.

(3) *Action at corps area headquarters.*—(*a*) Individual projects costing more than $5,000, and individual projects, irrespective of cost, involving new construction or material alterations as defined in paragraph 5*a*(1), AR 30-1435, will be forwarded quarterly to The Adjutant General with the recommendation of the corps area commander, in ample time to permit action by the War Department prior to the beginning of the quarter in which the work is to be done.

(*b*) Individual projects costing more than $1,000 and not more than $5,000, which do not involve new construction nor material alterations as defined in paragraph 5*a* (1), AR 30-1435, will be acted upon finally by the corps area commander.

(4) *Exempted stations.*—(*a*) Individual projects at certain exempted stations enumerated in paragraph 5*c*, AR 30-1435, costing more than $5,000, individual projects costing more than $1,000 at all other exempted stations, and individual projects, irrespective of cost, involving new construction or material alterations as defined in paragraph 5*a* (1), AR 30-1435, will be forwarded quarterly to The Adjutant General, with the recommendation of the commanding officer, in ample time to permit action by the War Department prior to the beginning of the quarter in which the work is to be done.

(*b*) Individual projects costing not more than $5,000 at certain exempted stations enumerated in paragraph 5*c*, AR 30-1435, and individual projects costing not more than $1,000 at all other exempted stations, which do not involve new construction nor material alterations as defined in paragraph 5*a*(1), AR 30-1435, will be acted upon finally by the commanding officer.

(5) *Data required.*—(*a*) In general, these estimates for individual projects must contain sufficient information to enable the officer reviewing them to form a clear conception of the necessity for doing the work and the benefit that the Government will derive therefrom.

(*b*) The following specific data will be given:

1. Age of existing installation and original cost.

2. Present condition.

3. Necessity for the expenditure.

4. Cost data and sketches in sufficient detail to permit of checking and analyzing.

5. EMERGENCY WORK.—*a*. Work which normally requires the approval of higher authority may, in an emergency, be done without such approval, but only in case the necessary funds are available and upon the written order of the commanding officer, who will state in the order that the necessary funds are available at the station.

b. If the necessary funds are not available, a brief report and request for funds will be made by telegraph.

c. A brief statement of the nature of the emergency will be made upon the voucher for payment, and a copy of the order of the commanding officer will be filed therewith. See AR 35–180 and 35–740.

d. W. D., Q. M. C. Form No. 105 is to be submitted for emergency requirements whatever the cost, when funds are not available within the corps area, or at an exempted station, in an allotted status, and it is desired that the funds be made available by the War Department.

e. The foregoing provisions as to emergencies have no application to fortification work under the Corps of Engineers.

b. In order further to facilitate the proper preparation of Form No. 95, detailed instructions pertaining to this form are issued annually by The Quartermaster General. A copy of "Instructions on the Preparation of Annual Report for Defense of the Budget for Fiscal Year 1940—Q. M. C. Form No. 95," is included in appendix I. It should be clearly understood, however, that changes in instructions for the preparation of the annual estimates are made annually by The Quartermaster General, and the instructions which were issued for fiscal year 1940 are included only as a guide as to what may be required annually from post quartermasters.

45. Form No. 103.—*a*. This report is prepared whenever a building at a post is occupied, and the report is rechecked when the building is vacated or another responsible officer is placed in charge of the building. The form provides spaces for detailed notation as to the condition of the building itself, the condition of the Government owned furniture, and other equipment contained therein. Inasmuch as this inspection is made in the presence of the responsible occupying officer and the quartermaster (or his representative), the report establishes any damage that may have been caused by the responsible occupant during his term of occupancy. After obtaining information relative to the damage, it is then possible to determine whether

it is the result of fair wear and tear or the carelessness of the occupant.

b. The secondary purpose of the report is to record the readings of the electric and gas meters (if any), the amount of fuel on hand, and the disposition of the keys for the building. The occupant of the building signs the report.

46. Form No. 104.—*a.* This report shows (in addition to other items) the cost of all labor and materials expended for maintenance and repair work on each building, structure, and system on the post. Specimen copy of this form is included in appendix I. The purpose of the report is to provide an up-to-date record showing—

(1) Cost of repairs to each individual building, etc., during the fiscal year (column 4). These costs are taken from the duplicate copies of Form No. 106 completed during the year which have been segregated by building numbers. In this connection, see paragraph 7 of "Instructions on Preparation of Form 106" as to distribution of overhead.

(2) Total cost of repairs (column 5) since each building, etc., was constructed. This column is simply a total of column 4 of this report and column 5 of the report of the previous year.

(3) Cost of original building plus the cost of all alterations and additions to June 30 (column 6). No maintenance or repair items are included in this column; only those items which actually change the physical structure itself. The cost of such alterations and additions made during the fiscal year are reported in column 7 and similar items should be noted on W. D., Q. M. C. Form No. 117, as previously explained in chapter 2, section III.

(4) Replacement value (column 8) is only an estimate which fluctuates from year to year as the costs of labor and material fluctuate. It represents the best judgment of the utilities Officer as to the cost of replacing each individual building or structure at the present time.

b. Method of preparation.—Form No. 104 is prepared by C-3, who uses the duplicate copy of each completed work order (Form No. 106). These work orders are segregated according to building numbers and systems, and the total amount expended during the fiscal year is then determined and entered on the form opposite each building or system. At the same time, these work orders should be scrutinized to determine whether or not any of them covers alterations or additions which should be entered on the historical records.

47. Form No. 105.—For individual projects involving new construction or major alterations, and for all individual projects (in excess of $1,000), for expenditures on any one building or system at any one

time, detailed estimates of the cost of each project are required to be submitted to higher authority on Form No. 105. (See AR 30-1760 quoted in par. 44.)

48. Form No. 106.—*a.* The use of Form No. 106 has already been discussed. However, it is emphasized that the form is prepared in triplicate and each repair job should be covered by a separate work order; for example, a work order to "repair plumbing in Building No. 8 during the month of July" should not be issued, as such a practice, while saving paper work, inevitably results in abuse and failure to keep accurate records of costs.

b. It frequently happens that construction materials or supplies, such as lumber, nails, roofing material, etc., are issued by the quartermaster to organizations on the post, with which material they are to accomplish such repair work as the quartermaster is unable to have done by the utilities personnel. In such cases, before such supplies are released by the Supply Division, a work order should be issued, as in the case of any other repair job, to cover materials only, with notation on work order that labor will be furnished by the organization concerned.

c. As a further aid in the preparation of Form No. 106 the following detailed instructions by The Quartermaster General are quoted:

1. Maintenance and repair work should be accomplished in accordance with Army Regulations:

AR 30-1435	AR 30-1475	AR 30-1505	AR 30-1515
AR 30-1580	AR 30-1620	AR 30-1625	AR 30-1635
AR 30-1660	AR 30-1670	AR 30-1675	AR 30-1680
AR 30-1685	AR 30-1690	AR 30-1710	AR 30-1715
AR 30-1760	AR 30-1770	AR 30-1775	AR 40-585

and only by the authority of the quartermaster or his authorized representative, and the cost of all work thus performed should be entered on work order Form No. 106.

2. When repair requests are received, the work order and report clerk should prepare Form 106 in triplicate. The original should be sent to the mechanic who is to perform the work and the duplicate and triplicate retained in the quartermaster's office for checking and follow-up. Individual work orders will only cover work properly chargeable to one project.

3. When the work is complete and accepted as satisfactory by the person requesting the repair work, the workman will carefully fill in the form in every detail, showing the number of mechanics and the time they were employed with the actual amounts of material that were used, whether surplus, salvage, or purchased from current appropriations. The work order should then be returned to the quartermaster's office.

4. The work order and repair clerk will then check the completed work orders and enter all costs. When project No. 1 personnel (considered a part of the regular operating personnel of the post) have been used, no money value will

be shown for their time. This will be taken care of as an overhead percentage, etc., charged annually to all buildings and utilities, as explained below. He will also make notation on the work order of the number of units that were repaired. The cost data that are on the original order will be copied on the duplicate and triplicate copy of work order. He will then classify the work order in accordance with the projects as shown in a subsequent paragraph and place the original completed work order in a file corresponding with the project number. The duplicate copy will be filed by building numbers. The triplicate will be used as a voucher to the stock records. No posting should be done, as this increases clerical labor needlessly.

5. When preparing Q. M. C. Form 95 during September or October the previous fiscal-year file of original work orders that were filed by projects will be totaled to secure the data upon which to base the entries "Expended Fiscal Year 19——."

6. On June 30 of each year the duplicate copy of work orders filed by building numbers will be totaled and used to compile the data required by Q. M. C. Form 104. Work order files should be retained for four fiscal years and then destroyed. These files should always be kept up to date and available to inspecting officers.

7. Employees paid for under salary appropriations pertaining to project No. 1 positions, which include clerks, professional employees, plant operators, fire department and key utility personnel, etc., are considered as a general overhead operating charge. In order to provide an equitable distribution of their salaries while absent on leave or through sickness and while doing no actual repair work; also when making repairs themselves; and to provide for time unaccounted for by repair project mechanics when not being charged on the work order form Q. M. C. 106, or when absent due to leave or sickness.

a. When project No. 1 employees make repairs themselves.—Their time actually spent on the job will be shown on the work orders covering the details of the repairs actually made, but no money value will be entered for this work.

b. Project No. 1 personnel.—At the close of each fiscal year ending June 30th, the pay of all project No. 1 personnel should be prorated and entered as a charge to all buildings and utilities at their respective stations. Thus, if the cost of project No. 1 personnel amounts to $6,200, and there are sixty-two (62) buildings and utilities (such as street lighting systems, water system, sewer system, sewerage disposal plant, etc.) at the station, each building and utility will be charged at the rate of $100 annually, and this amount entered as a charge in addition to other repair charges and included in the amount reported on Q. M. C. Form 104. The cost of project No. 1 personnel is provided for on Q. M. C. Form 95, as shown in the instructions on the preparation of that form. On Q. M. C. Form 95 they are entered directly under project No. 1 operating personnel and opposite the appropriation to which applicable.

c. Repair mechanics and laborers paid for under repair projects.—(Not project No. 1.) To cover the time unaccounted for on work orders, after considering the method shown in paragraph 8 for charging the time actually at work on repair jobs, as when they are absent on leave or sickness, will also be entered as an overhead expenditure, and at the end of each fiscal year prorated against each building and added to the other repair cost of each building and utility on Q. M. C. Form 104 in the same manner as explained in subparagraph *b* above. This amount will also be added as an operating overhead on Q. M. C. Form 95.

8. Civilian mechanics and laborers employed under the various repair projects (but not under project No. 1) will be charged for at an hourly rate for the actual number of hours worked, based on an eight (8) hour day, based on 280 working days to the year. This allows for 52 Sundays and 52 Saturday half-holidays and seven (7) regular holidays. All the time absent due to leave or sickness, or not accounted for by the reason that they were not employed on specific work orders, will be included in the general overhead, and charged at the end of each fiscal year as indicated above in paragraph 7 *c*.

9. Enlisted men's time on work orders will be charged at the rate per hour shown on Q. M. C. Form 95 issued each year for each hour actually at work. This figure is estimated to represent the amount of funds that would be required to replace the enlisted men now used by civilians should at any time higher authority decide that this is necessary.

10. All materials will be charged for and a money value shown. There should not appear any such items as "material salvaged" or "material taken out of buildings, no charge." However, if the invoice value of materials used is not available, it will then be necessary to use the present market value for cost purposes. In the case of salvaged material, or material removed from buildings due to changes in installation, the cost thereof should be made equal to the amount of money that would be required for the same articles in the same condition were they purchased at the present time and under present conditions.

11. Each quartermaster should endeavor to keep overhead operating charges to a minimum, as this office has requested the Inspector General's Office, on the annual visit of inspection, to look into the method of handling of work orders. Reports received through the Inspector General's Office indicate that many stations are not handling the work orders in the proper manner, and these instructions are being issued as a separate pamphlet in order to bring them to each quartermaster's attention and at the same time to simplify and clarify existing instructions.

49. Forms Nos. 108 and 108A.—*a. General.*—AR 30–1760 and 30–1620 require that an annual report on heat, light, and power be submitted on Form No. 108 at the end of each fiscal year to The Quartermaster General; also that an extract report on heat, light, and power on Form No. 108A be submitted to reach The Quertermaster General before January 5 of each year. Specimen copies of these two forms are included in appendix I.

b. Form No. 108.—(1) On this form are recorded the amount of solid and liquid fuel (coal, wood, coke, kerosene, etc.) issued for each individual building and system (including issues to each utilities plant). Such issues made during the fiscal year are determined from the individual issues as recorded on Form No. 437. Spaces are also provided on Form No. 108 to show the annual consumption of gas and of electric current for light and for power for each individual building and system, the consumption being determined by the meters in each building.

(2) At the end of the report, space is provided to show the consolidated status of each type of fuel for the fiscal year as follows:

(*a*) On hand last report July 1.

(*b*) Over, Short & Damaged (picked up).

(*c*) Received since last report.

(*d*) Total to be accounted for.

(*e*) Consumed July 1 to date this fiscal year.

(*f*) Over, Short & Damaged (dropped).

(*g*) Transferred to other stations.

(*h*) Drop from stock record cards.

(*i*) On hand this report (individual bins included).

(*j*) Total accounted for.

(*k*) Under contract not delivered.

(*l*) The details involved in making up report will be understood by a study of the specimen copy of Form No. 108 in appendix I.

c. Form No. 108A.—This is a consolidated report showing status of fuel and electric power consumption at the end of the first 6 months of the fiscal year. For each type of solid and liquid fuel and of electric current (for light, power, and cooking) it shows—

(1) Balance on hand at beginning of fiscal year.

(2) Amount received since beginning of fiscal year.

(3) Total to be accounted for on December 31.

(4) Consumption since beginning of fiscal year.

(5) Balance on hand December 31.

(6) Amount required for remainder of fiscal year.

(7) Amount on contract not yet delivered.

50. Form No. 118.—*a.* This report is a consolidated cost data sheet on operations of the following utility plants for 6-month periods:

(1) Central steam heating plants (individual heating plants not included).

(2) Electric generating plants.

(3) Refrigerating and ice plants (small individual refrigerators not included).

(4) Water pumping and treating plants.

(5) Sewage pumping and waste disposal.

(6) Fire protection.

b. A specimen copy of this report is provided in appendix I. Spaces are provided on the report for recording all costs of labor, operating supplies, electric power, fuel, repairs, and other items required in the operation of each utility plant at the post. A record of the total output of each plant is kept on operating logs; therefore,

the total unit cost of production for each plant can be readily ascertained, i. e., the cost per kilowatt hour for electric power, cost per 1,000 gallons of water pumped, etc. The unit costs of production are compared with the prices obtainable from private plants and, where the private plant can provide a rate more favorable to the Government, the post plant is placed in a "stand by" condition and the commercial service is utilized. The unit costs of production for similar utility plants at various posts are also studied with a view to bringing all costs down to as low a figure as possible.

c. In calculating the total operating cost of each plant, ordinary maintenance and repairs (but not major repairs) are included. The method of making up this report will be understood by a study of Form No. 118 in appendix I.

51. War Department Form No. 17 (Report of Boiler Inspection).—*a.* All steam boilers (portable, stationary, locomotive, locomotive crane, or marine) are required to be inspected at least once a year excepting—

(1) Boilers operated at less than 20 pounds' pressure.

(2) Boilers not in service.

b. The boiler inspection report is made on Form No. 17 by representatives of the Steamboat Inspection Service, Department of Commerce, upon request by the quartermaster to the nearest local representative of that service.

c. After receipt of the inspection reports from the boiler inspector, work orders are issued authorizing any repairs necessary to correct defects found during the inspection. For complete details see AR 30-1775. A copy of Form No. 17 is included in appendix I.

52. Fuel and light allowances.—*a.* Although the reports, records, and estimates described above will enable The Quartermaster General to ascertain whether or not the utility plants at a station are being operated economically, such reports provide no data as to the operation of individual heating plants and lighting systems in barracks, quarters, etc. These separate lighting and heating installations are in reality small utility plants, and some form of supervision and control over them must be exercised in order to prevent carelessness and waste.

b. It is not practical to control the operations of these smaller heating and lighting installations in individual buildings by means of reports similar to those required for post utility plants because of the amount of paper work involved. However, control over such smaller installations is effected by the establishment of fair allowances of fuel, electric light, lamps, etc.

c. Detailed instructions concerning the method of establishing fuel and light allowances are contained in AR 30-1620 and 30-1625. Inasmuch as the computation of fuel and light allowances is an important administrative duty of the utilities officer, and because the proper control over fuel and light consumption will result in substantial savings for the Government, he should study the foregoing Army Regulations carefully.

53. Special reports and estimates.—*a.* Reports of buildings damaged or destroyed, etc., are made to the War Department in accordance with AR 210-70. The post quartermaster furnishes to the commanding officer and to the board of investigation pertinent data regarding the building designation, estimate of the value of damages, and cost of repairs, etc. Such technical data are prepared by C-3 under the supervision of the utilities officer.

b. A report on utilities funds is made each quarter or oftener to The Quartermaster General. The report is prepared by the fiscal branch of the Administrative Division, office of the post quartermaster, after the utilities officer has been consulted with regard to the amounts set up for estimated requirements for the remainder of the fiscal year and the free balance, if any, of funds that may be withdrawn by The Quartermaster General.

c. The report on the disposal of surplus real estate is not made by the post quartermaster unless he is designated also real estate agent for the post. As soon as buildings are salvaged, immediate report is made in accordance with AR 30-1435.

d. Other special reports in connection with utilities are made in accordance with instructions issued by higher authority.

54. Distribution.—*a.* All reports made to higher authority (except exempted stations) are prepared in triplicate. The original is for The Quartermaster General, one copy for the corps area commander, and one copy for the files of the Utilities Division.

b. For posts exempt from the control of the corps area commander, only two copies of reports are required. The original is for The Quartermaster General and the copy for file at the post.

Part II

ENGINEERING AND TECHNICAL DATA

CHAPTER 1

GENERAL

55. General.—As stated in part I of this manual, the Utilities Division of a post, camp, or station functions under the direct supervision of the quartermaster thereat or under the direct supervision of one of his commissioned assistants who is designated the utilities officer. The duties of the utilities officer are divided into two general classes as follows:

a. Administrative duties.—The administrative duties of a utilities officer have already been set forth in detail in part I of this manual

b. Technical duties.—The technical duties of a utilities officer are discussed in detail in this part of the manual. In general, they comprise—

(1) Preparation of plans and specifications for minor repair projects to be accomplished or for construction materials and supplies to be purchased.

(2) Inspection of construction materials when received at the post, camp, or station.

(3) Issuing of necessary instructions to the technical personnel for accomplishment of maintenance, repair, and operation activities; continuous supervision of work in progress; and final inspection of all completed work.

(4) Study of all operation records in order to determine whether or not the technical personnel is operating efficiently and to determine the practicability of making changes in the various utilities plants in order to reduce operation costs.

56. Applicable Army Regulations.—In the preceding chapters, reference is made to certain War Department and other regulations. The Army Regulations applicable to utilities are enumerated below, and the utilities officer and his technical personnel should familiarize themselves with the contents of these publications:

30-1435, Construction.
30-1475, Heating Systems—Stoves and Ranges.
30-1505, Target Ranges and Shooting Galleries.

30–1515, Water-supply Systems.
30–1580, Fire Protection and Fire Fighting.
30–1620, Standard Quantities of Heat, Light, and Electric Power.
30–1625, Electric Plants and Systems.
30–1635, Charges for Electricity and Gas.
30–1660, Refrigeration.
30–1670, Incinerators.
30–1675, Railroads.
30–1680, Roads and Walks.
30–1685, Clearing, Draining, and Improving of Grounds.
30–1690, Wharves, Docks, and Sea Walls.
30–1710, Sewerage Systems.
30–1715, Drainage—Storm Sewers.
30–1760, Maintenance of Utilities.
30–1770, Historical Record of Public Buildings, Structures, Systems, and Utilities.
30–1775, Inspection of Steam Boilers.
30–1780, Steam Boilers; Installation, Operation, and Maintenance.
40–585, Construction and Repair of Fixed Hospitals, Veterinary Hospitals, and Quarters for Medical Department Noncommissioned Officers in Time of Peace.

57. Additional sources of information.—The technical information which follows is necessarily limited as it is not feasible in a manual of this type to treat in detail all of the numerous engineering features of materials, cost estimating, and plant operations. Sufficient information is included to enable utilities officers, with the aid of the technical personnel of the Utilities Division, to function. The utilities officer can broaden his knowledge of the technical phases of utilities by a study of textbooks and handbooks dealing with the various subjects. The following list includes some of those available:

American Civil Engineers' Pocket Book by Mansfield Merriman, published by John Wiley & Sons, New York City.

Kidders' Architects' and Builders' Pocket Book, published by John Wiley & Sons, New York City.

The Building Estimator's Reference Book, published by Frank R. Walker, 168 N. Michigan Avenue, Chicago, Ill.

Sanitary Refrigeration and Ice Making by J. J. Cosgrove, published by the Standard Sanitary Mfg. Co., Pittsburgh, Pa.

Household Refrigeration, published by Nickerson & Collins Co., Chicago, Ill.

Handbook on Electrical Engineering by Foster, published by D. Nostrand & Co., New York City.

Practical Electricity by Croft, published by McGraw Hill Book Co., New York City.

Rules of National Electric Code, copies of which may be secured from Underwriters Laboratories, 382 Ohio Street, Chicago, Ill.

CHAPTER 2

MATERIALS OF CONSTRUCTION

SECTION I

ACCEPTANCE TESTS

58. Materials of construction.—*a. General.*—All construction materials and supplies utilized by the Utilities Division are of commercial manufacture and are easily procurable under competitive bids. Specifications for such materials set forth the requirements for each material used. In order to determine whether or not the delivered materials are in accordance with the specifications, it is necessary to perform one or more of the three following tests:

(1) *Chemical tests.*—Chemical tests are very commonly used in commercial testing. They are generally made to determine the presence and amount of certain ingredients such as carbon, sulphur, and phosphorous in steel. A chemical analysis does not, however, give complete information as to the nature and properties of a material. Two pieces of steel may show the same chemical composition but in a testing machine may develop widely different degrees of strength.

(2) *Microscopic tests.*—Microscopic tests, especially in the use of metals, are used to ascertain the structure and texture of the material and whether flaws exist in it. This method is largely used in research work.

(3) *Physical tests.*—Physical tests are those used to determine the physical properties such as appearance; compression, tensile or shearing strength; fineness or coarseness; absorption of water, etc. Test results are valueless unless the specimens are truly representative of conditions and properties under investigation.

b. Testing as a basis of acceptance.—The use of testing as a basis of acceptance is the most reliable and fairest method to both the dealer and the Government. Where facilities are not available at a post, camp, or station, it is possible to have such tests performed by the Bureau of Standards or by the testing laboratories of State, city, or educational institutions.

c. Requirements for certain materials.—The list of construction materials used by the Utilities Division is so large that it is practical in a manual of this character to discuss the requirements for only the most common materials, as hereinafter set forth in this chapter. Detailed requirements for other construction materials may be found by consulting the specifications described in paragraph 59 and by consulting standard engineering textbooks, manufacturers' catalogues, and engineering publications.

59. Specifications.—The characteristics of the various construction materials used by the Utilities Division are found in the specifications listed below:

a. Project specifications.—These are written for a definite construction project, such as an addition to a building or an extension to a sewer system. While many provisions of such a specification are applicable only to the project, this specification also contains references to Federal and United States Army specifications for certain materials (paints, hardware, plumbing materials, etc.), if such specifications have been published.

b. Federal standard specifications.—These cover various materials used by the departments and independent establishments of the Government. When a Federal standard specification has been approved for any material, it must be used by all departments and independent establishments, and no other specification may be substituted therefor.

c. United States Army specifications.—These cover various materials commonly used by the War Department but for which no Federal specifications have been prepared. It is obligatory upon all arms, services, and bureaus of the War Department to use the United States Army specifications wherever applicable.

d. Index to specifications.—A pamphlet entitled "Index of United States Army and Federal Specifications used by the War Department" is published yearly and should be in the files of every utilities officer. In the purchase and inspection of materials and supplies, care should be taken that (wherever applicable) these specifications are used.

SECTION II

LUMBER

60. General.—Lumber has been used as a structural material from the earliest times. It is less costly than iron, steel, or concrete but on the other hand is liable to destruction by fire and to decay.

a. Classification.—The woods most commonly used are placed commercially in two classes, hardwood and softwood. The common practice has been to call the broadleafed trees "hardwoods" and the conifers or cone-bearing trees "softwoods," although in some cases this is not exact, as some broadleafed trees are of the soft variety while some conifers are of the hard variety.

b. Uses.—For general structural purposes, the softwoods are much more generally used than the hardwoods. The principal uses of the hardwoods are for interior finish, flooring, furniture, wharf construction, and railroad ties.

c. Order of importance.—The woods most commonly used in the order of their economic importance are about as follows:

(1) Southern yellow pine, including the longleafed and shortleafed, is found in the Southern States from Virginia to Texas, most of the present supply being from Louisiana, Mississippi, and North Carolina. Longleafed pine is generally hard, heavy, tough, stiff, and strong, highly durable in dry localities and fairly so in contact with the ground, while the shortleafed is greatly variable in these qualities. The southern yellow pines are the most important sources of timber for heavy construction and provide also a great deal of lumber for joists, posts, piling, and general building construction. When treated with preservatives, the harder woods of this group make good ties, dock or pier fenders, bridges, piling, etc.

(2) White pine is found to a limited extent in the States north

of the Ohio River and east of the Dakotas. It is a soft, uniform whitewood, which shrinks very little in seasoning, works easily, and nails without splitting. It is not very strong but quite durable and is excellent for interior trim, doors, sash and shelving.

(3) White oak, found principally in the central portions of the United States, is a hard, heavy, strong, tough, dense wood, durable in contact with the soil, but shrinks considerably and is liable to checking during seasoning. This oak is the most valuable of the hardwoods, and is excellent for the better quality of interior trim, finish, flooring, stair treads, and thresholds.

(4) Red oak, found in approximately the same localities as white oak, is somewhat lighter and weaker, and less durable in contact with the soil, but is easily impregnated with preservative materials. Not only can it be used in lieu of white oak as a measure of economy, but it also is excellent for wood piling and railroad crossties.

(5) Douglas fir is grown along the Pacific coast and is a strong, brittle, and fairly durable wood, being the best structural timber of the Northwest. It is widely used for building construction, dimension timbers, ties, piles, etc.

(6) Spruce, although a softwood, is widely used in the Northeast for lighter building framing. It has a fiber stress of about 60 percent of longleafed yellow pine, but exceeds that of certain grades of shortleafed yellow pine. It is also used to a considerable extent for concrete form work and for shelving. It is not durable when exposed and unprotected.

(7) Cypress grows along the eastern and Gulf coasts from Maryland to Texas, along the Mississippi Valley, and in Florida and Georgia. It is a light softwood of medium strength, difficult to season, but very durable. It is used principally for siding, shingles, interior trim, sashes, doors, etc.

(8) Hard maple or sugar maple grows in all the States east of Colorado and most abundantly in the Great Lakes Region. It is a hard, heavy, tough, strong wood, but not durable, and rots even during the seasoning process. It is used principally for flooring and interior finish.

(9) Red gum is a hard, tough, and close-grained wood found throughout the South. It takes a high polish and is therefore used extensively for veneered work such as doors, furniture, etc. It is not durable when exposed to the weather.

(10) Redwood grows abundantly along the coast of California. It is a light, straight-grained wood, used for all kinds of lumber, ties, shingles, poles, paving blocks, sash, painted interior trim, etc.

(11) White cedar is found along the eastern coast and around the Great Lakes and is used for interior trim and door frames.

(12) Red cedar grows in the region east of Colorado and north of Florida. Both red cedar and white cedar are light, soft, weak, and brittle woods, valuable on account of their low shrinkage and great durability when exposed. They are used for siding, posts, poles, shingles, etc.

(13) Ponderosa pine, also known as western pine, includes all timber sold in California, Oregon, and Washington as white pine and is suitable for studding, rough sheathing, shelving, and interior trim that is to be painted.

(14) Norway pine, also known as red pine, is a light, hard, close-grained wood with few pitch pockets. It is suitable for general construction purposes.

61. Structure of timber.—*a.* Examination of the cross-section of a piece of full-grown structural timber generally reveals the fact that it usually has a small pith at the center of the cross section, surrounded by numerous concentric rings of wood which are, in turn, encircled by the bark. These concentric rings represent the wood added each year during the life of a tree and furnish, therefore, valuable information regarding the age, rapidity, and uniformity of its growth. If these rings are examined closely, it will be noticed that each ring is made up of an inner, softer layer called the "spring wood" and an outer, darker layer called the "summer wood."

b. Trees grown in the open or after a forest has been cleared are called "second growth" trees and exhibit wider rings than those grown more slowly in the forest. Generally the rings are widest at the center, becoming narrower near the bark. The comparative width of the annular rings and the direction and arrangement of the cells and fibers (these latter are determined microscopically) are the causes of the grain of the wood. Trees having wide annular rings give coarse-grained wood, while those of slower growth or woods with narrower annular rings give the finer-grained wood.

c. When the wood elements run straight or parallel to the pith of the wood, the wood is said to be straight-grained, and as straightness of grain is of great importance in wood beams and tension members, careful examination should be made to eliminate cross-grained or spiral-grained timber. The splitting locally of a small stick is about the only safe test for detecting spiral grain; that is, grain running spirally through the timber. As a general rule, split timber is stronger than sawed timber.

62. Defects in timber.—Defects in timber which affect it from a structural standpoint are knots, checks, and shakes.

a. Knots are the beginnings of branches which have been surrounded by the parent stem, and are either sound or loose knots. A sound knot is one occasioned by a portion of the branch being incased by the parent stem while living, while knots incased after the limb has died will make either a loose or a decayed knot. Sound knots are generally much harder than the surrounding wood. In general any knot will affect the workability, cleavability, shrinkage, and strength of the wood. Knots which occur in coniferous woods, such as the pines, are likely to be filled with resin which makes them difficult to cover with paint.

b. Checks are radial cracks produced by unequal stresses set up in the lumber during the seasoning process. The checking varies largely with the kind of wood being seasoned.

c. Shakes are classed as ring and heart. A ring shake is the separation between adjacent annular rings, often invisible in the green timber, but becoming apparent after seasoning. Heart shakes are radial cracks emanating from the pith in the trunk of very old trees. Shakes and checks affect adversely the durability of timber because they readily admit moisture and air.

63. Seasoning.—*a. Methods.*—It is essential that wood be properly dried or seasoned by appropriate storage or artificial drying. If seasoning is properly done, the wood is less subject to shrinkage and warping after it is placed in a structure; with reduction of weight, its resistance to decay is increased; strength and mechanical properties are improved; and its condition is responsive to preservative treatment. Two methods of seasoning are used, namely, air-drying, and kiln-drying.

(1) *Air-drying.*—(*a*) In air-drying, the temperature and humidity conditions of the atmosphere exercise an important influence upon the rate of drying. Thus, ties and structural timber cut in the summer dry out at a much more rapid rate than those felled in the late autumn. In fact, oak and gum timber felled in the summer often dry too fast; hence, for such timbers the cooler months are more favorable for seasoning.

(*b*) In air-drying or seasoning of wood, it is customary to place the lumber piles so that the successive layers of the material are separated by narrow strips of lumber placed transversely of the length of the timber, usually three or four strips to the length of board or timber, with the adjacent timbers in each layer separated by

as much as an inch. The wood is piled in this way, either under cover or in the open, protected by a roof or any material which will keep out moisture.

(*c*) The requisites for seasoning wood well are warm temperatures and plenty of air circulation. Some of the large conifer timbers require two seasons of open air-drying while smaller timbers require only one summer.

(2) *Kiln-drying.*—Warm, moist air or superheated steam is the drying medium in most schemes for kiln-drying lumber. The temperatures in the kilns vary from 70° to 180° F., and the drying periods are from a few days to several months in length. For the most successful kiln-drying, the timber should be brought to as high a temperature as it will endure without injury. This is done before drying is begun; otherwise, the moisture in the hot outer fibers of the wood tends to flow toward the cooler interior. The proper condition is obtained by circulating air with a high humidity until the wood is thoroughly heated and then gradually diminishing the humidity to bring about the drying. Among the advantages over air seasoning that result from kiln-drying are the following: Greater reduction in weight, and consequently in shipping charges; reduction in moisture content to any desired value, which may be lower than that obtainable through air seasoning; reduction in drying time below that required by air seasoning; and killing of any stain or decay fungi or insects that may be in the wood.

b. Direction of shrinkage.—Lumber, as ordinarily supplied, is seldom well-seasoned. It shrinks perceptibly across the grain, whereas shrinkage lengthwise or with the grain is negligible. All girders, joists, etc., will shrink and warp and partitions constructed on them will settle.

64. Moisture content.—The moisture content of "dimensional lumber and sheathing" will not exceed 19 percent in any case. In lumber for wood finish, sash, and doors it will not exceed 12 percent in any case. Upon delivery, samples of lumber are weighed, placed in an oven at about 220° F. for 4 hours, and then weighed again. The loss in weight divided by the weight of the dry sample gives the moisture content.

65. Durability a variable factor.—The durability of wood is a decidedly variable quality. If well-seasoned and kept in a dry place, or immersed in water, or if buried in the ground, it may last for centuries. However, when impregnated with and subject to moisture, air, and moderate warmth, it decays; the rapidity of this

decay depending upon external conditions, the kind of wood, and its preliminary condition and structure.

66. Causes of decay.—*a. General.*—One cause of decay is the action of bacteria, a very low form of plant life which multiplies by cell and spore division and which attacks the organic substance in wood. The growth of fungi, a form of plant life which lives through the destruction of other plants, also tends to cause wood decay. Decaying timber is recognized by its lack of resonance when struck with a hammer, its ready absorption of abnormal quantities of water, its odor, and its unnatural color.

b. Dry rot.—Dry rot is caused by the fermentation and breaking down of the chemical compounds of wood by a certain fungus introduced in the presence of moisture. It is brought about by lack of proper ventilation. Confined air with much moisture encourages the growth of fungi. These lower organisms excrete ferments which dissolve parts of the cell walls, render the timber brittle, and so reduce cohesion of fibers to the extent that they become powder. Dry rot is prevalent in such ill-ventilated places as the wall pockets at the ends of floor timbers and in the core of timber columns in mill construction. It is indicated by the swelling of the timber, change in color, the gradual covering of the timber with mold, and the emission of a musty odor. Sometimes reddish and yellowish spots appear on the timber. It is difficult to eradicate when once present, the only remedy being to remove all traces of the fungus and to disinfect the wood.

c. Wet rot.—Moisture, especially in the presence of warmth, will dissolve the substance of the cell walls of sapwood and cause the decay of lumber. Wood felled between the months of April and October is especially subject to wet rot. It usually appears when wood is kept damp or is subjected to alternate dryness and moisture. It communicates itself to sound portions of wood by actual contact only. If all rotten wood is cut away and the remainder kept dry, wet rot will have no further effect.

d. Common rot.—Common rot is manifested by the presence of external yellow spots on the ends of timber sticks and often by a yellowish dust in checks and cracks, especially where the pieces are in contact. The cause of common rot is improper seasoning in badly ventilated sheds.

67. Powder post, pole borer, and termite.—Although decay is the principal cause of deterioration, a great deal of damage is done annually by the attacks of insects. Three of the land variety are the powder post, the pole borer, and the termite.

a. The powder post deposits on the surface of the wood eggs which hatch into small white grubs. These grubs bore into the wood and transform it into a fine powder. They develop very rapidly and the deterioration of the infested timber proceeds quickly. All bark should be removed from air-dried lumber used in buildings.

b. The pole borer is a grub hatched from the eggs of a reddish-brown beetle near the ground line of poles and posts. It bores into the wood and transforms it into a reddish-brown dust. It attacks both sound and decayed timber, but is not active in the latter if it is water soaked.

c. (1) Termites are not true ants, although they look much like them and live like them in large colonies consisting of the various species. The winged male and female termites which are seen "swarming" for a short time in the spring or fall are on their way to start new colonies. These parent termites are not injurious, but their descendants, the wingless workers of the new colony, are very destructive. These are rarely seen, because they do not crawl about in the open but stay in the earth, underground, or in wood. If they want to reach woodwork above ground, they build earthlike tubes to crawl through. Termite damage is always hidden inside the wood. The interior rafters, joists, beams, or other timbers of a building may be entirely eaten out before the insect vandals are noticed, the reason being that they leave a protective outer shell.

(2) To prevent termites from getting into a building, it is highly desirable, where practicable, to eliminate wood from foundations, cellars, and basements and to substitute therefor concrete or other stone equivalent for basement floorings, as well as elimination from basements of any other structural wood, including wood substitutes, such as fiber, composition boards, and other substitutes containing cellulose. Timber or lumber can be used safely in buildings if it is raised a suitable distance above possible soil contact by the use of rock, concrete, or brick foundations made with standard grades of mortar; or if suitably capped and if metal shields are put on to shut off passage tubes.

(3) In repairing termite-damaged buildings, the same suggestions as those given for the construction of new buildings apply. The damage by termites is becoming a very serious problem to structures in the United States, and great care should be taken in the construction of buildings to prevent such damage.

(4) This information about termites is taken from U. S. Department of Agriculture Leaflet No. 31, June 1929. A more complete description of termites and their habits is contained in Farmers' Bulletin No. 1472, U. S. Department of Agriculture, 1926.

68. Marine borers.—Timbers placed in water are subject to attack by two classes of marine borers, representing the mollusk and crustacean types, which infest waters along the Atlantic and Pacific coasts.

a. Teredo.—(1) Of the worms most destructive to wood, the teredo navalis or shipworm, a species of mollusk, is the most active. It deposits its eggs on timber immersed in water. From these soon emerge small but rapidly developing worms. The head of the worm is equipped with a shell-like substance, shaped like an auger, by means of which it bores its way into the timber in a direction generally parallel to the grain. As it progresses, it lines the hole with a calcareous deposit and maintains communication with the outside through the small lids at the external opening. The teredo continually increases in size as its boring progresses, and specimens varying from one-fourth to one-half inch in diameter and 15 inches to 3 feet in length have been found.

(2) Its habitat is the salt water of the warmer climates, though occasionally it is found in cold water. It avoids fresh water entirely, always prefers clear to muddy water, and is most active in the vicinity of calcareous shores. It may be found at work from half-tide level down to the ground. The teredo attacks timber piling in an area between mean tide and low water and about a foot above mud line. It has been known to ruin untreated timber in less than 1 year. The teredo prefers unpolluted water, and avoids harbors in which the waters are heavily laden with sewage. The installation of municipal sewage treatment plants sometimes results in a rapid increase of teredo growth in harbors. Various methods have been used to prevent action of the teredo. The method ordinarily used is creosoting piling before use or incasing in concrete.

b. Wood louse.—The crustacean is known as the limnoria or wood louse and grows to the size of a grain of rice, boring into the wood by means of sharp jaws. It lives on food obtained from the wood substance, which it penetrates readily to a depth of about ½ inch per year. It is active only in clear, still water, and confines itself to a line or belt around the low-water line. It is particularly active in the Gulf of Mexico and along the north Pacific coast. Untreated piling can be destroyed by limnoria within a year in heavily infested harbors.

69. Preservative treatments.—*a. Methods.*—The preservation of timber is accomplished generally by the use of coal-tar creosote and zinc chloride; however, preservative materials should not affect seriously the strength of the wood. Zinc chloride is not suitable

when exposed to the weather as it is soluble in water and will leach out. In all the various methods used, the principal aim is to fill the pores of the wood with preservative material to such an extent that no additional preservative can be injected. This may be accomplished in various ways.

(1) In one method the timber is treated in a preliminary vacuum for a short length of time, possibly an hour, afterward subjected to a pressure from 100 to 180 pounds per square inch to secure penetration, and then all surplus preservative is taken from the wood by the means of a vacuum.

(2) Another method is to place the timber in a retort filled with compressed air, at a pressure of about 150 pounds, and this pressure continued until the wood refuses to absorb further preservative. It is nearly always specified how much preservative per cubic foot the material is required to absorb. It has been found through a series of tests that the use of the preservatives mentioned does not affect the strength of the wood.

b. Preservative materials used.—In general, the pressure processes of preserving timber are the most satisfactory. The various preservatives used are coal-tar creosote, water-gas tar creosote, and wood-tar creosote, zinc chloride, mercuric chloride, and copper sulphate. Mercuric chloride and copper sulphate are not much used in the United States. The latter has the disadvantage of attacking any iron or steel in contact with the wood. It is found that the coal-tar creosote is used for approximately two-thirds of the timber treated annually.

70. Strength of wood.—*a.* The strength of timber is affected by a great many factors, and for this reason the safe working stresses for members of timber structures are very much lower than the ultimate strength. In other words, it is necessary to use a large factor of safety, depending on the use to which the structure is to be put.

b. One of the factors affecting the strength of timber is the grain of the wood. Under compression parallel to the grain, wood, in proportion to its weight, is one of the strongest of structural materials. Because of this it is much used for columns and posts. Timber, however, does not have a well-defined elastic limit because it takes set, or permanent deformation, when low loads are applied. Those species of wood having the greatest compressive strength parallel to grain are oak, longleafed pine, white ash, Douglas fir, or west coast hemlock.

71. Grading commercial lumber.—All commercial lumber is graded under local classification rules issued by various lumber associ-

ations. Quartermasters should be governed by Federal Specification MM-L-751a, which cities the applicable grading rules. They should secure the classification rules from local dealers and familiarize themselves with their contents. There are many grades and kinds of lumber, all of which are fully described in these classification rules. By careful study of rules and observation of material, one can, in a short time, identify with a reasonable degree of accuracy the different grades and kinds of lumber.

72. Classification of lumber.—*a. By size.*—According to the "simplified Practice Recommendation R16-29, Lumber (4th Edition)", lumber is classified by size as follows:

(1) *Yard lumber.*

(*a*) *Strips.*—Yard lumber less than 2 inches thick and under 8 inches wide.

(*b*) *Boards.*—Yard lumber less than 2 inches thick, 8 inches or over in width.

(*c*) *Dimension.*—All yard lumber except boards, strips, and timbers; that is, yard lumber 2 inches and under 5 inches thick and of any width.

NOTE.—Dimension—planks and joists—to be used where working stresses are required should be considered and graded as structural material.

1. Planks.—Yard lumber 2 inches and under 4 inches thick and 8 inches and over wide.

2. Scantlings.—Yard lumber 2 inches and under 5 inches thick and under 8 inches wide.

3. Heavy joists.—Yard lumber 4 inches thick and 8 inches or over wide.

(*d*) *Board measure.*—All yard lumber is sold by board measure. To compute the board measure in any piece of yard lumber, divide the sectional area in square inches by 12 and multiply the result by the length of the piece in feet. A board foot is a piece of lumber 1 foot square and 1 inch thick.

(2) *Structural material.*

Timbers.—Lumber 5 inches or larger in least dimension.

b. By manufacture.—According to manufacture, lumber is classified as follows:

(1) *Rough lumber.*—Undressed as it comes from the saw.

(2) *Surfaced lumber.*—Lumber that is dressed as it comes through a planer.

(3) *Worked lumber.*—Lumber which has been run through a matching machine, sticker, or molder. Includes matcher, shiplapped, and patterned lumber.

(4) *Grain.*—Material is considered vertical (or edge, quarter-sawed, rift) grain when the annular rings (grain) form an angle of 45° or more with the surface of the piece, and all other material is classed as flat (or slash) grain.

Section III

BUILDING STONE

73. Stone.—*a. Use for structural or ornamental purposes.*—Since the earliest times, stone has been used as a material of construction. Today, however, the use of stone masonry for purely structural purposes is of diminishing importance, owing to the great development of reinforced concrete; but building stone is still used for buildings and structures in which appearance and permanence are factors in design.

b. Varieties.—The common building stones include granite, limestone (including marble), sandstone, and slate. There are many varieties of each of these general classes. The granites are the hardest and strongest building stones in general use, the sandstones are next in hardness and strength, and the limestones are, in general, the softest and weakest (though the stronger limestones are stronger than the weaker sandstones). The use of slate is, in general, confined to roofing and some interior work in buildings. The harder and stronger a building stone is the more difficult and expensive it is to quarry blocks of that stone and to dress them to shape.

74. Stone masonry.—*a. Classification.*—Stone masonry may be classified as riprap, rubble, squared or cut stone, or ashlar.

(1) *Riprap.*—Riprap consists of stone piled together without mortar and is used in low stone walls and for river bank protection. It has very little structural strength and is not used for structures subject to any great load.

(2) *Rubble.*—Rubble is uncut or roughly shaped stone piled and cemented with a mortar matrix. In uncoursed or random rubble the stones are piled without any attempt at regularity of arrangement. In coursed rubble the stones are placed in layers arranged as regularly as possible.

(3) *Squared stone.*—Squared stone is stone dressed to a fairly good face, laid up in mortar, as in foundations and building walls.

(4) *Ashlar.*—Cut stone or ashlar is stone cut into blocks, squared with fairly smooth surfaces.

b. Strength of stone and of stone masonry.—Stone masonry is used in structures principally to resist compressive stress. Individual blocks of stone are sometimes used to resist bending, such as the lintels for windows and doors, or as top slabs for culverts. The strength per square inch of specimens of stone is very much greater than the strength per square inch of masonry built from that kind of stone because of the presence in masonry of mortar joints which are weaker than the stone. The actual strength of stone masonry depends largely on the strength of the mortar used and on the closeness of fit between adjacent stones. Ashlar masonry is about seven times as strong as uncoursed rubble masonry.

SECTION IV

MATERIALS FOR CONCRETE

75. Cement.—*a. General.*—Cement and water mixed with an aggregate consisting of large particles (usually broken stone or gravel) and small particles (sand) form an artificial stone which is called "concrete."

b. Portland cement.—Although a natural cement was in general use until recent years, this product has been entirely superseded by Portland cement, which is an artificial mixture of lime-bearing materials with clayey materials; burned in a kiln to the point of incipient fusion and afterwards ground to a fine powder.

(1) *Weight and containers.*—Portland cement weighs 376 pounds per barrel, or 94 pounds per sack, the package in which it is now usually shipped. In proportioning concrete one sack is considered 1 cubic foot. A barrel is equivalent to four sacks.

(2) *Storage.*—Cement used in construction work should be stored on platforms built at least 18 inches above the ground, in order to secure ample ventilation and circulation of air, and it should be kept dry at all times. During damp, wet periods it may become hardened from the moisture of the air causing it to set. It should not be used when it has reached this condition.

76. Aggregates.—*a. General.*—Sandstones are not often used as they are usually deficient in strength and have not the toughness of the traps or limestones. In all coarse aggregate long, flat, and soft particles should be rejected as being unsatisfactory in concrete.

b. Gravel.—A very excellent material to replace broken stone is washed and screened gravel, which, though often rounded in shape,

is usually hard, and makes an excellent and strong concrete, but it is inferior to either crushed stone or crushed gravel for use in surfaces subject to wear and abrasion, such as the wearing surface of highways or floors.

c. Slag.—Slag is sometimes used in concrete construction, and cinders also are used where the concrete carries only light loads or is for fireproofing purposes. A common use of cinder concrete is as a filler for roof construction over concrete. If cinders are used they should be hard, clean, and free from sulphites, unburned coal, and ashes.

d. Crushed stone.—Fifty percent of the total stone output is used as crushed stone and it is made from various kinds of limestone, granite, and trap rock.

e. Trap rock.—Trap rock covers the heavy, dense, igneous rocks which are of dark color and which, through rapid cooling in formation, are of very fine grain. They are tough and rather difficult to quarry, but when crushed make good road material and aggregate for concrete. The kind of crushed rock to be used depends usually on the nature of the rock available in the locality where the construction is carried on.

f. Sand.—(1) Sand may be defined as hard, granular rock material, passing a ¼-inch screen, and coarser than dust. Sand of silicious quartz, granite, feldspar, or similar material is best for concrete work. Sand should be free from more than 10 percent vegetable loam, organic matter, and should be free from deleterious foreign substances. It should be graded from coarse to fine in order to give a very dense mixture free from the excessive voids which would occur if grains were all of one size.

(2) The common specification in reference to size is that it shall pass a ¼-inch mesh screen. All material which does not pass this screen is considered as coarse aggregate, that which passes being considered fine aggregate. The sand passing a ¼-inch screen is considered suitable for all classes of concrete work, while in mortar work it is customary to use only that which will pass through a No. 8 sieve.

Section V

STRUCTURAL CLAY PRODUCTS

77. General.—Brick, tile, terra cotta, and drain and sewer pipe are some of the common structural clay products used at posts, camps, and stations. These products are all made from clays or shales, the difference depending largely upon the character of material used and its method of manufacture. Clay suitable for making common building brick is found in large deposits in many localities throughout the country.

78. Brick.—*a. Building brick.*—(1) Building bricks are made from clay and from lime and sand. Sand-lime bricks are usually restricted in use to backing up since they are apt to be more porous than clay. Clay brick ranges from the common brick made from surface clays to face brick made of the better grades of shale or impure fire clays. The essential qualities of clay are sufficient plasticity for proper molding, low shrinkage in drying and burning, and low fusibility.

(2) *Requirements of good brick.*—Good brick should be free from checks or cracks, should emit a metallic ring when struck by a hammer, and should exhibit a fine-grained, uniform, dense structure. Burned face brick should not be easily scratched by a knife. Brick should also be uniform, both in color and size. Regularity in size is of special importance for bricks used in highly stressed walls, and they should be free from soluble salts, such as the sulphates of lime, magnesia, and the alkalis which are likely to produce efflorescence. It is a mistake to require that only the hardest burned brick be supplied to every job. Soft or underburned brick has enormous strength. For much interior work, backing up of walls faced with harder burned brick, for fire, party, and division walls, and in general any location where absorption is not a factor and where great strength is not required, advantage may be taken of the lower cost and sound serviceability of soft or salmon brick. Salmon brick has an unexcelled bonding surface on which to plaster direct. For the uses which may be made of salmon brick, see Federal Specification SS-B-656, paragraph I-3.

b. Paving brick.—Paving brick should be made from shales, and the finished brick should be free from marked distortion, checks, cracks, and blisters, and should have one plane edge. It should give a high metallic ring when struck with a hammer and should, when broken, exhibit a uniform close-grained structure free from lamina-

tion, and should have a crushing strength in excess of 8,000 pounds per square inch.

c. Refractory brick.—Refractory brick is a class of brick used to line flues, hearths, and various classes of furnaces utilized in metallurgical processes. Refractory bricks must be able to withstand high temperatures without undue softening or change in volume, must resist the action of gases and slag generated during the process, must resist abrasion when hot, and must possess low thermal conductivity.

79. Building tile.—*a.* Hollow blocks, partition tile, and fireproofing tile are made from shale mixed with clay, which will burn to a hard, dense structure.

b. Hollow blocks, frequently termed load-bearing tile, are used in load-bearing walls and partitions and combination flat slab concrete and hollow-tile floors.

c. Partition tiles are used for partitions that carry no superimposed load. They are not as hard and strong as hollow blocks.

d. Fire-proofing tile differs from partition tile chiefly in size and shape. Tile for outside walls may be salt glazed on one side, scored or smooth on one or two sides. Plaster or stucco walls, of course, require scored tile.

80. Roofing tile.—Roofing tile of various shapes and patterns, called Mission tile, Panama tile, Spanish tile, is frequently used. Such tile is made of a clay which can be dried and burned without suffering any appreciable distortion. Roofing tile should be strong, durable, free from soluble salts, and impervious to water. The chief objections to tile for roofing are the expense and heaviness of construction, but these objections are offset by the pleasing architectural effects obtained by their use.

81. Architectural terra cotta.—Architectural terra cotta is used in lieu of ornamental stonework as an expedient to cut down the cost and yet to secure the general effect of carved stonework. Architectural terra cotta is made from a very finely ground mixture of fire clay and shale, cast in molds, dried, and then burned at a high temperature between 1,100° C. and 1,300° C. Special effects are secured by spraying the surfaces to be exposed with a slip coat of the required color.

82. Drain pipe.—Drain pipe or tile is made principally from shales and impure clays. The tile when formed is burned in a variety of kilns, sometimes with brick or fireproofing. The temperatures are lower than those used in sewer pipe, though the better grades of tile are burned until steel hard. Drain tile is generally cylindrical in form, is laid with uncemented butt joints, through which drain-

age water seeps. The sizes of drain tile vary from 4 to 42 inches in internal diameter.

83. Sewer pipe.—Sewer pipe is made from red burning clays, fire clays, shales, and mixtures of shale and fire clay. This pipe is sometimes called vitrified, but the burning temperature is frequently insufficient for vitrification. Salt glazing is supposed to insure a smooth, impervious surface. The pipe is made in lengths of about 3 feet and in diameters up to 42 inches. Sewer pipe is commonly provided with bell and spigot ends. After laying, joints are packed with jute or similar material and cement mortar. The crushing strength in pounds per linear foot of sewer pipe will vary from 1,500 to approximately 3,000 pounds. Sewer pipe must have high strength in order to carry the load of earth material when in trenches and be hard enough to withstand the action of acid and gases in sewage. A smooth interior surface is highly desirable.

84. Limes and plasters.—*a. Quicklime.*—Lime, quicklime as it is generally called, is made by burning limestones which have the requisite properties. When properly burned, quicklime should possess the following qualities: It should be in hard lumps, free from cinders or clinkers, and should slake readily in water forming a smooth, fine paste, without residue. It should dissolve in soft water.

b. Hydrated lime.—Hydrated lime is quicklime thoroughly slaked by the aid of machinery.

c. Gypsum and hard wall plasters.—There are many hard wall plasters (which have a gypsum base) on the market. Such hard wall plasters are carefully prepared by the manufacturers and give uniformly good results when installed in a building.

d. Sand lime brick.—As a substitute for the clay brick, sand lime brick is used when a light colored wall is desired at moderate expense. Sand lime bricks are made from a lean mixture of slaked lime and fine silicious sand, molded under mechanical pressure, and hardened under steam pressure. The resulting bricks have a smooth surface, even shape, and uniform color. They do not resist fire or frost action as well as the clay brick.

Section VI

METALS

85. Ferrous metals.—Iron and steel are used in many forms in connection with the activities of the Utilities Division. It is only possible in this manual to refer to the most commonly used forms in which they are utilized.

a. Structural steel for buildings.—Structural steel is a medium steel manufactured by either the Bessemer or open-hearth processes and rolled from billets into structural shapes. These shapes are known as bars, angles, tees, channels, I-beams, etc. These shapes are cut, punched, assembled, riveted, and bolted together and otherwise manufactured, according to specification, into different parts of a structure, such as columns, girders, etc., and made complete so as to be easily erected at the building site.

b. Reinforcing steel for concrete.—Reinforcing bars are manufactured from new billet steel and rail steel. The United States Department of Commerce has established the intermediate grade as the single standard for billet steel reinforcement, but mild and structural grade bars are rolled. Rail steel is lower in price and is accepted in many public and private rod specifications for straight bar use. Deformed bars are almost universally used. These bars are rolled in a restricted number of standardized sizes and are deformed either round or square in section. The deformed bar increases the mechanical bond with the concrete.

c. Cast iron.—Cast iron is used for water pipe, soil pipe, structural columns, and many other purposes. The chief varieties are gray cast iron, which is relatively soft, and white cast iron, which is extremely brittle yet so hard that it cannot be machined. Malleable cast iron is white cast iron brought to a malleable condition by an annealing process. It is stronger than gray cast iron, but inferior in strength to steel castings. It shrinks less than steel, is smoother and freer from blow holes, and more resistant to corrosion than steel castings. Because of its strength, great toughness, and moderate cost, it is much used for small castings, such as car couplings, journal boxes, door fastenings, hinges, pipe fittings, stove plates, hardware, etc.

d. Wrought iron.—(1) Wrought iron is a malleable iron and contains so little carbon that it does not harden or temper when rapidly cooled. It is almost the same as the very low carbon steels except that it is never produced by melting and casting in a mold, but is always forged to the desired size and form. It usually contains less than 0.12 percent of carbon. Its chief distinction from low-carbon steel is that it is made by a process which finishes it in a pasty instead of a liquid form, and leaves about 1 to 2 percent of slag mechanically disseminated through it. It is very tough under repeated shocks and has been used

frequently in place of soft steel for certain types of shafting. One of its most valuable purposes, however, is the facility with which portions of it may be united by squeezing or hammering at high heat rendering it very useful to the smith; this property being due to the high plasticity of the iron through a considerable range of temperatures.

(2) Wrought iron is used for spikes, nails, bolts, nets, wire, chains, horseshoe bars, sheets, plates, pipes, tubing, armatures, etc. Before 1890 wrought iron was used very much in bridge and structural building work but since that date structural steel is used instead. Structural steel costs less than wrought iron and is 20 percent stronger.

86. Nonferrous metals.—In addition to iron and steel, the other metals most commonly used are copper, zinc, lead, and tin, and the alloys of copper and zinc, and copper and tin which form, respectively, the brasses and bronzes.

a. Copper.—Copper is used very largely in copper sheets for roofing, downspouts, gutters, flashings, water pipe, electric wire, etc.

b. Zinc.—Because of its resistance to atmospheric corrosion this material is used as a coating on steel sheets, pipe, etc., and such materials are then said to be galvanized.

c. Lead.—Lead is used in the form of sheets; as a calking compound in joints of cast iron pipe; as lead pipe and as an alloy with tin for coating roofing sheets, etc.

d. Tin.—An alloy consisting of about 25 percent of tin and 75 percent of lead is used to coat sheets of mild steel or iron in the manufacture of roofing tin, which is used a great deal at Army posts.

e. Brasses.—The principal alloys used are the brasses and bronzes. The brasses contain from 60 to 90 percent copper and from 10 to 40 percent zinc, and range from silvery white for alloys carrying little copper to copper red for those containing little zinc.

f. Bronzes.—Bronzes contain 5 to 25 percent tin and 75 to 95 percent copper and may be regarded as a kind of hardened copper. The bronzes are now used chiefly because of their hardness and noncorrosive properties.

87. Corrosion of metals.—*a. Iron and steel.*—Iron and steel corrode rapidly under certain conditions. Moisture, heat, the presence of carbon dioxide, chlorine, and other gases are important factors in bringing about the corrosion of these metals, although there exists a wide diversity of opinion as to the reasons for the corrosion.

b. Cast iron.—It has been found that corrosion of iron by hot water is lessened by the removal of air. Cast iron, however, has shown remarkable durability when exposed to conditions which readily affect steel and wrought iron.

88. Electrolysis.—Cast-iron pipes are affected by what is known as electrolysis, which is the flow of electric current from street railway rails, for example, through the soil to the pipes, following the latter to some point where it again leaves the pipe to return to the rails. This action affects the iron to such an extent that it is possible, where action has gone on for some time, to drive nails completely through the cast iron. This condition is remedied somewhat by bonding rails, insulation of the pipe from the earth, use of double trolley for carrying the return current on insulated overhead wire, and the use of alternating instead of direct current for the operation of streetcars.

89. Galvanizing.—To overcome the ravages of rust, over 60 percent of the zinc produced in this country and imported is used for galvanizing. Galvanizing is the dipping of plate, wire, or other iron or steel article into a bath of molten zinc. The zinc, adhering to the iron wherever the surface has been thoroughly cleaned, forms a very effective protective coating. On first-class work two or more coats are usually applied, the zinc coating excluding the atmosphere or surrounding medium from the base metal and preventing decomposition.

90. Sherardizing.—Another method of protecting iron and steel from corrosion is sherardizing. This is effected by placing the article to be sharardized in an iron drum filled with a mixture of finely powdered zinc and zinc oxide in varying proportions, heated in a reducing atmosphere for a period of time depending upon the thickness of the coating desired, the article undergoing treatment being constantly rotated. By this process, the surface of the article becomes an alloy of iron and zinc and forms a continuous effective protection to the metal beneath. Sherardizing is more effective than galvanizing but is more expensive. It is used chiefly in the treatment of small castings.

Section VII

ROOFING MATERIALS, BUILDERS' HARDWARE, PAINTS, GLASS, AND OTHER MATERIALS

91. Roofing materials.—Many different materials are used for roof covering on the buildings under the jurisdiction of quarter-

masters at posts, camps, or stations. A brief description of the more common roofing materials is given below.

a. Tin and copper roofs.—(1) These materials have been previously described in paragraph 86. The tin roof consists of sheets of soft steel or wrought iron weighing 50 pounds per 100 square feet, coated with a mixture of lead and tin weighing 40 pounds per box of 112 sheets, 20 by 28 inches in size.

(2) For a copper roof, the copper is generally cut into pieces 15 by 30 inches in size, although larger sheets are used in valleys. Soft copper is used for the roof covering proper and hard copper for cleats, hanging gutters, downspouts, and counterflashings.

b. Slate.—Slate is a natural product that averages approximately ¼ inch in thickness. The sizes of slates generally used are 20 by 10 inches and 18 by 12 inches although other sizes are furnished for special designs.

c. Roofing tile.—This material has been previously described in paragraph 80.

d. Roofing felts and pitch.—Slag and gravel roofs consist of several layers of asphalt or coal-tar felt weighing 15 pounds per 100 square feet. Each layer is cemented to the layer below with asphalt or coal-tar pitch. Similar pitch is flowed on the exposed surface of the felt, and gravel or crushed slag is embedded therein. Such roofs cannot be used where the pitch is greater than 3 inches to the foot.

e. Composition roofing.—Slag or composition roofing cannot be used if the slope is steeper than 3 inches to the foot. In such cases, it will be necessary to use prepared roofing, or metal, slate, shingles, or tile. Prepared roofings are made at the factory by cementing three or more layers of felt together, then coating them with pitch or asphalt into which fine sand or ground glass is embedded.

92. Builders' hardware.—Under builders' hardware are included doorlocks, latches, butts and hinges, knobs, window lifts, catches, pulleys, and other special fittings for doors, windows, drawers, etc., which facilitate their operation. Such hardware is made of solid brass or bronze; wrought iron steel, plain, galvanized, or electroplated. The types and varieties manufactured by the many large hardware companies are so great that a selection of the various types of hardware to be used upon Government work is set forth in great detail in the Federal standard specifications.

93. Paints.—*a.* Paint is composed of—

(1) Primary constituents—

(*a*) Pigment.

(*b*) Vehicle.

(2) Secondary constituents—

(*a*) Thinner.

(*b*) Drier.

(*c*) Color pigment.

b. Included in the paint pigments are white lead (basic carbonate of lead), oxide of zinc, lithopone (barium sulphate and zinc sulphide), graphite, litharge, red lead, etc. Color pigments are divided into mineral, chemical, vegetable, and animal, each of which has its proper function in providing the desired color to the paint.

c. The vehicles, thinners, and driers include linseed oil, tung oil, soybean oil, menhaden oil, turpentine, liquid drier. mineral spirits, alcohol, etc.

d. The inspection of these various materials must be done very largely in the laboratory to determine if they meet the detailed requirements set forth in the applicable Federal standard specification. Where no Federal specification has been published, a special specification must be prepared for the product desired.

94. Glazing.—*a*. Many kinds of glass are used at posts, camps, and stations, such as sheet glass, plate glass, obscure glass, wired reinforced glass, etc., but because the largest amount of glass used is sheet glass the discussion will be restricted to this product.

b. Sheet glass is made by blowing a glass cylinder, cutting off the ends, cutting the cylinder longitudinally, and then heating and flattening it to an approximately flat surface. However, sheet glass due to its method of manufacture, has a more or less wavy surface, varies in thickness and has such defects as stain, string, blisters, etc. Sheet glass is graded as double thick (approx. 1/8-inch thick) and single thick (approx. 1/12-inch thick). Each thickness is divided into AA quality, A quality, and B quality in accordance with the number of defects present in the glass. A quality, double thick, sheet glass is generally satisfactory for the bulk of the glazing done at Army posts.

95. Plumbing, heating, and electric materials.—These materials will be discussed under later chapters dealing with these subjects.

CHAPTER 3

TYPES AND METHODS OF CONSTRUCTION

SECTION I

STRUCTURES

96. General.—In tracing the progress of modern building construction, we find in general that the older forms of permanent structures had massive self-supporting exterior and interior masonry walls extending from foundations to roofs. These walls supported the floor construction which was very simple in design, consisting usually of timber joists, with one or two thicknesses of wooden flooring. Whenever columns were used they were either of wood or cast iron. Brick piers were used to some extent in commercial and industrial buildings.

a. Wrought-iron beams.—At a later date wrought-iron beams were substituted for wooden beams, cast iron continuing to be used extensively for columns in the better grade of buildings. During this period the wrought-iron I-beam brick-arch floor construction was developed. This type of construction then was regarded as fireproof.

b. Steel replaces wrought iron.—Since the period just referred to, steel has almost entirely superseded wrought iron in floor and roof construction, and cast iron for columns in buildings. During the same period, steel gradually took the place of wood, cast iron, and wrought iron in bridge construction. Greater loads can be carried and longer spaces between supports can be spanned by steel structural members, trusses, etc., than was possible with the old types of construction which employed wood or a combination of cast iron and wrought iron.

97. Fireproofing.—In the early stages of structural development in metals, little attention was given the subject of fireproofing. The prevailing opinion seemed to have been that because metal would not

burn, structures built of it were fireproof. During recent years the fallacy of that practice has become very generally known. It is now the general practice in all important structures to cover all steel structural members with effective fire-resisting material.

98. Skyscrapers.—The first high buildings of the commercial type were constructed with massive self-supporting exterior walls, the floors and roofs being supported by columns and exterior walls. The foundations for the columns were independent of the wall foundations. During the past 30 years the high steel frame building or skyscraper reached its full development in this country. In this type the entire structure, including exterior walls, is supported by the steel frame.

99. Reinforced concrete buildings.—Reinforced concrete buildings have come into very extensive use during the past 15 years. In these structures the tensile stresses are all borne by the reinforcing metal. The concrete is subject to compressive and shearing stresses, but no dependence is placed upon it for tension. The very general use of this building material has been brought about not only because of lower cost of construction but because of its superior qualities, fire resistance, and great durability.

100. Types of structures.—*a. Classification.*—Building structures may be classified as—

(1) Light frame.
(2) Brick.
(3) Hollow tile.
(4) Mill construction such as is used for shops, warehouses, etc.
(5) Steel frame.
(6) Reinforced concrete.

b. Light frame buildings.—Light frame buildings consist of wooden frames supported on brick, stone, or concrete foundations and covered on the outside with weather boarding. The uprights or studs are usually composed of small timbers 2 by 4 inches in sections spaced ordinarily 16 inches center to center with sill at bottom and plate at top. The floor-supporting members or joists usually spaced 16 inches, center to center, are supported by the stud walls. In the framing of wooden buildings, three methods are usually employed—the braced frame, the balloon frame, and the Western or platform frame.

(1) *Braced frame*, also known as drop-girt frame. Only the corner posts are carried from foundation to eaves. Heavy girts are framed into the corner posts and the studs are "cut in" (fitted) between the girts.

(2) *Balloon frame*, in which the studs extend the entire distance from the sill (which rests on the foundation) to the plate (which

supports the rafters). The outer ends of the second floor joists rest on a ledger board let into the inner faces of the studs.

(3) *Western frame*, also known as platform frame. The supporting studs extend from the top of each tier of joists to the under side of the tier next above, the studs being provided with top and sole plates. The advantages are shorter members and more equal shrinkage than in the balloon and braced frame types, reduced heat losses and reduced fire risk.

c. Cantonment buildings.—Cantonment buildings, also called "temporary buildings," are similar in construction to the light frame buildings described in *b* above with the following exceptions. In order to provide economy of design and speed of erection, the superstructures rest on wooden foundation posts and the floor joists and partition studs are spaced 20 to 36 inches apart. The outside walls are covered with boards and battens and the wall studs are left exposed in the interior except in cold climates where they are covered with wall board. The designs of these buildings are standardized wherever possible as conservation of time is paramount and the architectural effect is of no importance. Detailed working drawings of all cantonment buildings have been prepared in the office of The Quartermaster General and are available for distribution upon request.

d. Brick buildings.—This term in general pertains to buildings whose exterior and main division walls are of brick. These walls are self-supporting and also support part of floor loads by carrying outer ends of floor joists; the interior supports of the floor being stud-bearing partitions, timber, or iron columns and girders, or piers of masonry with timber or iron girders. The advantage of brick buildings over frame are their semifireproof qualities and their permanence.

e. Hollow-tile buildings.—The method of construction of hollow-tile buildings is similar to that of brick buildings, hollow terra cotta blocks being used instead of brick. Walls are self-supporting and also carry part of floor loads. Tiles are laid with holes running vertically. Lintels are usually constructed of reinforced concrete.

f. Mill construction or slow-burning type.—(1) Mill construction consists of buildings in which exterior and main division walls are of brick, and the interior structural system of heavy timber. In this type the timber is placed in solid heavy masses so as to expose the least number of corners or ignitible projections to fire. The timbers being large, it is possible to place them farther apart, thus providing better accessibility for fire fighting and making it possible to reach all parts by sprinkler or hose.

(2) This system provides means for separating floors and adjacent

rooms from each other by use of noncombustible stops and by encasing stairways with either brick or other noncombustible partitions so that a fire will be retarded as much as possible in passing from floor to floor or from room to room. This construction is fire retardant but not fire resistant.

g. Steel frame buildings.—(1) Steel frame or steel skeleton buildings are those in which the entire load of the building is carried on a framework of steel columns, girders, and beams; the exterior wall girders and columns being designed to carry the weights of outside walls as well as that part of the floor loads and live loads that come upon them.

(2) In the skeleton type of construction any type of outside wall may be used, such as terra cotta, brick, concrete, tile, etc. These outside walls are of light construction and are known as "filler" or curtain walls. The floors are usually of reinforced concrete or hollow tile. All members of the frame are fireproofed, usually by encasing them with reinforced concrete, although other methods are employed. Steel frame buildings are considered fireproof.

h. Reinforced concrete buildings.—(1) Reinforced concrete buildings usually consist of the skeleton type of construction. A framework of columns, girders, and beams is built of reinforced concrete as in steel construction; the wall girders and columns, of course, being designed to carry the weights of outside walls as well as that part of the floor loads that come upon them.

(2) In the reinforced type of construction the floor is usually of reinforced concrete and is cast as an integral part of the structure.

(3) In the "flat slab" system the beams and girders are eliminated almost completely, if not entirely, and the slab is made to rest directly on the columns, the tops of columns being enlarged into extended caps. This type of construction permits of a shallower floor system than is ordinarily attainable. Reinforced concrete buildings are considered fireproof.

Section II

FOUNDATIONS AND FOOTINGS

101. Foundations.—*a. General.*—(1) In the building of any structure, first consideration should be given to foundation requirements and the local conditions affecting the stability of the soil upon which the foundation will rest.

(2) By foundation is meant the lowest portion or base of a structure; that which bears the load of the superstructure and transmits it to and distributes it over the supporting soil or foundation bed. The object of the foundation is to provide a safe and permanent base for the superstructure.

(3) The natural material on which the foundation rests is called the foundation bed. Walls, piers, and columns below the surface of the ground, or grade line, are generally designated foundation walls, piers, etc., to distinguish them from similar elements of the structure located above grade.

b. Area of foundation.—(1) In the case of foundations for ordinary structures where weight is the only force to be resisted and where weight is uniformly distributed over the foundation bed, the first problem will be: Over what area of foundation bed must the weight be distributed in order that the safe bearing capacity of the material of the foundation bed will not be exceeded?

(2) The safe bearing capacity of the foundation bed (expressed in tons per square foot) must be determined first. After this capacity has been obtained, the area of the foundation is secured by dividing the load that may come on the foundation by the safe bearing value of the soil.

(3) Thus, if the estimated weight (both dead and live loads) coming on a building pier is 72 tons, and the foundation bed is of clay that may be safely loaded with 2 tons per square foot, the area required will evidently be 72 divided by 2, or 36 square feet.

c. Eccentric loading.—Eccentric loading of foundation should be avoided as far as possible. This means that resultant pressure acting on a foundation should pass through the center of gravity of the foundation. Where it is not practicable to avoid eccentric loading, it should be properly provided for.

102. Foundation beds.—*a. Testing soil.*—In the case of more important and permanent structures, it is customary practice to test the bearing power of the foundation bed before proportioning the foundations. The usual method, when it is not necessary to extend the investigation to a great depth, is to excavate several pits. By means of these open pits, it is easily possible to examine carefully the soil and its stratification. This reveals the firmness of the material and its water content, and affords a means of determining the extent to which sheeting and bracing of banks will be necessary as the excavation progresses.

b. Loading tests.—Loading tests of materials forming the foundation bed are made to assist in determining its safe bearing capacity.

By this method only a rough approximation of the real safe supporting power of the soil can be obtained as the loads must, of necessity, be applied to a small area. The results obtained from such an area may exceed considerably those of the larger areas of the footings because of lateral distribution of stresses. This condition necessitates the use of a large safety factor. Figure 1 shows the standardized method of making loading tests on soils. The accepted safe load should not exceed two-thirds of the final test load.

c. Soils.—(1) *General.*—All investigations relating to foundations of structures involve soil and rock characteristics. Soils, exclusive of vegetable matter, consist of disintegrated and decomposed rocks. Any given soil, therefore, has characteristics which are traceable to the rock from which it was formed.

(2) *Classification.*—Soils may be classified as sedentary and transported. The former consists of decomposed rock formed in its original position. The latter is a product of erosion which has been transported by water currents, ice, or wind, and deposited at points usually very distant from its source.

(*a*) The sedentary soils are more dependable for foundation beds than the transported soils. The former material is composed of coarser particles, such as fragments of rock and coarse sharp gravel and sand, whereas the latter material is composed of finely divided matter.

(*b*) Alluvial and wind-blown soils are the least dependable for foundation beds.

d. Solid rock.—Solid rock, also referred to as bedrock or ledge, is rock in its natural geological position and forms the most dependable foundation bed. It is capable, in the case of the hard rocks like granite, trap, and hard limestone, of sustaining any load that may be placed upon it.

e. Disintegrated rock.—Disintegrated rock, or soil formed in its original position, is often found to conform with the underlying solid rock. It makes an excellent foundation bed for structures of ordinary weight. Excavations for foundations for very heavy structures are carried through this material to the solid rock beneath.

f. Gravel and sand.—Masses of loose fragments of rock, boulders, and gravel are good foundation beds if underlaid by solid rock. Compact gravel and coarse, sharp sand are excellent foundation bed materials, and when laterally confined offer high resistance to foundation loads. The resistance of such materials to loads is affected by the depths of the formation and the character of the underlying strata whether they are rock or soft compressible soils.

g. Clay.—Clay is a general term applied to a large class of fine-grained cohesive soils. It is hard when dry but plastic and easily deformed when saturated with water. The clays vary widely in physical characteristics. Some are wholly unsuitable as foundation soils, while others are very satisfactory, especially when kept in proper condition by means of surface and subsoil drainage.

h. Safe loads for soils.—The allowable pressure on the soil, in pounds per square foot, will not exceed the following amounts, and the assumed bearing value will be noted on the drawing:

Soft clay	2,000
Ordinary clay and dry sand	3,000
Stiff clay	4,000
Coarse sand and gravel	6,000

Special investigation will be made for important structures and the foundations designed to conform to conditions found. If character of soil is not known, design for 3,000 pounds per square foot and note on drawings.

i. Filled ground.—All artificial fills and some natural fills are liable to a more or less uniform but continuous settlement or shrinkage, due to the gradual consolidation of the material of which the fill is composed. Where the fill is of solid rock this consolidation may amount to little, but where the fill is of earth, and especially where it is of mixed materials, the shrinkage will not only be large in amount but will continue for a very long period.

j. Sloping sites.—In case the site of a proposed building is a sloping area of ground, and especially if steep, there may be danger of slipping of the material forming the foundation bed.

k. Water in soil.—Water in the subsoil is very objectionable as it tends to lessen the resistance to lateral displacement and diminishes the bearing power of the soil.

l. Beds, part rock and soil.—It frequently occurs in some localities that the excavations for foundations are partly in rock and partly in soil. In such cases, all foundations should either be carried to solid rock, or the rock area excavated to a foot or more below the required grade for soil and then the area refilled with earth. The material on the refilled area should then be thoroughly consolidated and the surface brought to the required grade. In this way unequal settlement of foundations may be avoided.

m. Piling.—(1) There are situations where the natural subsoil is unsuitable material to form a safe and reliable foundation bed. If the material is wet and compressible, it is the customary practice

to drive a sufficient number of piles into it to carry the entire load without dependence upon the supporting power of the soil. The piles are either of wood, cast in place or precast concrete piles, or structural steel H-shape. If piles are of wood, they should be cut off at such grade as to insure permanency of saturation to retard decay, and steel H-piling is usually coated and protected from ground water level up to grade with a heavy concrete casing for the same purpose.

(2) The bearing power of the piles should be predetermined by loading tests of piles on the site or by computations using standard formulas before the foundation is designed. Actual tests form a much more reliable basis for computation than formulas. The piles should be sufficient in number to carry safely the maximum weight of the structure and all live loads. They should be so placed that each will carry its proportionate part of the entire load.

103. Footings.—*a. Concrete construction.*—Footing courses are today almost universally constructed of Portland cement concrete. The concrete may be either plain or reinforced.

b. Battered footings.—(1) Unless the plain concrete footing courses have the proper depth for width, they may fail due to vertical shear. This is most liable to occur in the case of concentrated loads such as those transmitted by columns and piers. The footings may also fail by rupture due to bending. Footings which are heavily loaded should be battered or stepped up, making an angle with the horizontal of not less than 60°. The load then becomes well distributed over the base. However, to insure against rupture by bending, it is generally more economical to use one course and reinforce it with steel bars rather than to spread the footing by stepping.

(2) Formerly pier and foundation walls for buildings were constructed of stone or brick masonry but today concrete is the material generally used.

Section III

BRICKWORK, PLASTERING, AND OTHER CONSTRUCTION WORK

104. Brickwork.—Brick structures should be built of the best quality of hard, well-burned bricks. In specifications it is required that the brickwork will be laid up in strict conformity with the lines and dimensions given on drawings; all walls to be plumb and true; and each course level and vertical joints properly broken. The bricks should be set on a full mortar bed and then shoved into place. The end joints should be completely filled with mortar.

105. Bond in brickwork.—*a.* Mortar is not so strong as brick. It can be readily seen that if each brick in a wall were placed directly upon another brick any great weight imposed might cause the vertical mortar joints to split open. A brick wall, if built correctly, must be tied together so that as much as possible of the strength of the brick will be utilized. Aside from the quality and character of the material, this tying together or bonding of a wall contributes most to its strength.

b. Bonding brickwork is the process of laying bricks across one another so that one brick will rest on parts of two or three bricks below it. This amounts to the same thing as "breaking joints." When built in this manner it is difficult for a wall to fail without breaking the brick. In all bonding, the aim is to prevent the vertical joints from forming a continuous straight line.

c. When bricks are placed lengthwise on the face of a wall they are termed "stretchers"; when placed crosswise so that only the ends are exposed to view on the face of the wall they are called "headers." A "course" means the thickness of a brick and a mortar joint.

d. The bonds principally employed are—

(1) *English bond.*—Although not much used in the United States, the English bond is probably the best and strongest method of bonding brickwork. In this bond header and stretcher courses are laid alternately. This is without doubt the best and simplest method to follow in all work where strength is required, for by using it a complete and thorough transverse bond is formed.

(2) *Flemish bond.*—In the Flemish bond each course is composed of a header and stretcher alternately.

(3) *American or running bond.*—The bond most extensively used in the United States is known as the American or running bond. This bond is sometimes called the garden bond. It consists of laying from four to seven courses and bonding with a row of headers at regular intervals. This bond enables the bricklayer to build a larger amount of wall in a given time than can be accomplished by the use of either the English or the Flemish bond.

106. Mortar for brickwork.—*a.* Mortar for brickwork is generally composed of 1 part Portland cement to 3 parts of sand and 10 pounds of hydrated lime to each bag of Portland cement used. The addition of hydrated lime not only makes the mortar more impervious to moisture but also makes the mortar more workable with the trowel.

b. In lieu of the Portland cement-lime mortar above described, a mortar composed of 1 part of masonry cement and 3 parts of sand by volume is equally satisfactory.

c. Lime mortar is sometimes used for brick and stone masonry when economy is desired. To make it, a mixture of 1 part lime and 2 parts of sand is commonly used. Lime mortar should not be used where any but moderate loads are to bear upon the brickwork or where the full loading is to be applied before mortar has had time to harden.

107. Strength of brickwork.—As a rule the strength of brickwork is about one-fifth the strength of the brick itself, according to the kind of mortar used to support a bond. Two hundred pounds per square inch is a heavy safe load when cement mortar is used and 150 pounds when lime mortar is used, although in certain cases much greater loads than these have been carried.

108. Wetting bricks.—In summer it is necessary to wet bricks before laying them so that they will not weaken the mortar by rapidly absorbing the water from it. Neglect in this particular is the cause of most of the failures in brickwork. However, the bricks should not be wet to the point where there is no absorption left or where the walls will slide and so destroy the bond. Nor must brick be wet so much as to destroy the stiffness of the mortar used for thick joints, because if the mortar softens the joint will slump to less than the required thickness. Do not wet brick laid in freezing weather; bricks should be thoroughly dry and without any coating of ice.

109. Efflorescence.—Efflorescence, or the white coating frequently seen on the outside of stonework and brickwork, is caused by soluble matter in the mortar which, being dissolved in the water used in mixing, is deposited upon the surface of the wall, as the water

evaporates. These deposits are in some cases carbonate or sulphate of soda, nitrate or carbonate of potash, or sulphate of magnesia. There is no way of preventing efflorescence except by coating the bricks with some preparation to make them impervious to water.

110. Plastering.—Plastering is the application of a plastic material, called mortar, to the walls and ceilings of a building. The plaster may be laid directly on the face of the wall or it may be applied on wooden, gypsum, or metal lath, which allows part of the mortar to be pressed through and fold over on the inner face, thus forming a key which holds the plaster in position.

111. Furring and lathing.—On brick or stone walls lathing is usually attached to vertical furring strips 1 inch thick by 2 inches wide, set 12 or 16 inches on centers. By this means, there is left an air space between the plaster and the wall, thus insuring a continually dry plaster surface. In frame buildings, the lath is attached directly to the studs forming the framing of the walls and partitions.

112. Lath.—*a. Wooden.*—Lath made of pine, spruce, or hemlock should be straight-grained, well-seasoned, free from sap and rot, clear of shakes and large or loose knots and, to prevent the subsequent discoloration of the plaster, should be free from live knots and resinous pockets. The regular size of a lath strip is ¼ inch by 1½ inches by 4 feet, the length regulating the spacing of the furring strips, studs, and joists. Lath is nailed in place in parallel rows, the edges being kept a full ¼ inch apart to enable the soft plaster to be pressed through and form a key.

b. Metal.—Metal lath is made of wires woven together in a square or triangular mesh or of expanded metal or perforated sheet metal. Wire mesh lath is made of 18 to 21 gage wire with about 2½ meshes to the inch. It is made in rolls 100 and 200 feet in length and 32 to 36 inches in width. It is sometimes stiffened by means of V-shaped bars. Expanded metal lath is formed by cutting slits in a sheet of metal and stretching it apart. This process forms stiff sheets of lathing that require no stretching when placed on the wall. It is fastened to the studs or furring with staples, and to metal furrings with wire. The lath is coated with asphaltum, painted, galvanized, or japanned to prevent corrosion.

113. Grounds.—Wooden grounds should be set around all openings to take the door and window architraves and where needed for bases, wainscotings, picture moldings, etc.

114. Corner beads.—In good work it is customary to reinforce all projecting corners with metal corner beads, which are secured to the studding or to brick or metal surfaces in a suitable manner, and are

buried in the plaster with the exception of a very narrow fillet at the corner.

115. Plastering materials.—The substances that enter into the composition of plastering mortar depend upon the nature of the surface to be coated, the order in which the layers are applied, and the desired finish. For ordinary work they are lime paste, sand, hair, wood fiber, and plaster of paris.

a. Lime.—Lumps of lime are deposited in a wooden slaking box and liberally sprayed with water; they soon begin to swell, crackle, and fall into a powdery mass which when mixed with the water form a smooth paste called slaked lime. This process is called slaking.

b. Sand.—Sand should be well screened, washed, clean, hard, sharp, silicious and free from loam, silt, or other impurities and should meet the following requirements:

Percentage retained:	*Maximum*	*Minimum*
No. 4 sieve	0	0
No. 8 sieve	10	0
No. 30 sieve	80	15
No. 50 sieve	95	70
No. 100 sieve	0	95

Weight removed by decantation not more than 5 percent.

c. Hair or fibre.—Hair or fibre should be reasonably free from dust, grease balls, and knots, and should be from ½ inch to 2 inches long. Fibre when used should be a vegetable fibre, long, clean, well brushed out and free from tannin.

d. Plaster of paris.—Plaster of paris is obtained from gypsum by gentle calcination. It is very soluble in water which renders it unfit for external use. The great value of plaster of paris is that paste made from it rapidly sets and acquires full strength in a few hours. Its volume expands in setting, making it a good material for filling chinks and holes in repair work.

116. Mixing mortar.—Mortar should be mixed in tight boxes. It is usually mixed by manual labor, but on extensive works and in cities it is often prepared by mortar mills, a more thorough incorporation of the ingredients and a tougher paste being produced by the machine process. It is essential that the lime should be thoroughly slaked. In much of the lime used there are more or less overburnt, hard, obstinate nodules, which resist the permeation of water and fail to disintegrate; these must be removed from the lime by screening, otherwise a pitted appearance of the finished work will invariably ensue from the future slaking of the particles.

117. Three-coat work.—Plastering is generally done in three coats on wood or metal lath and in two coats upon terra cotta, concrete, and brick surfaces. For three-coat work the process of applying and finishing the layers is described in the order in which they are applied.

a. Scratch coat.—A cementitious material composed of 3 parts of hydrated or quick-lime putty and 1 part of portland or Keene's cement should be prepared in a batch of such size that it will be used in 1½ hours. It should be mixed by volume and composed of 1 part of the above cementitious material, 2 parts of sand, and 1 bushel of hair or fiber per cubic yard of sand. Also, it should be tough, hold well together, and yet soft enough to be pressed between the lath to bulge out behind and form the key. The thickness of the layer should be fully ¼ inch. After the coat has hardened somewhat, it is scratched over diagonally by wooden comb-like blades. The grooves fulfill the same functions as the space between the lath to allow for a good key for the subsequent layer.

b. Brown coat.—The second coat is applied when the scratch coat has become dry; it is called the brown or floated coat because its surface is worked by means of board trowels called floats. The brown coat is composed of—

1 part of hydrated or quicklime putty.
3 parts of sand.
½ bushel of hair or fiber per cubic yard of sand, when brown coat is applied to masonry.

c. Finishing coat.—The third or finishing coat is designated by various terms, such as skim coat, white coat, putty coat, sand finish, etc. In all cases the material is applied to the wall in the form of a stiff paste by means of a steel trowel and is spread uniformly over the surface to a thickness of about ⅛ inch. It is composed of 2 parts of hydrated lime or quicklime putty plus 25 percent by weight of calcined gypsum (plaster of paris). The coat is put on with a trowel, floated down, and then polished to a glazed surface with a trowel, the surface being kept moist by water applied with a brush.

118. Hard wall plasters.—While with the use of the best materials and with proper care in preparation and application, a good wall may be obtained with lime plaster, there are so many uncertainties about it that numerous substitutes have been brought into use which have proved valuable and efficient. These are known under the general name of hard wall plasters. Gypsum plaster is the one most commonly used. The method of applying these plasters

is essentially that described for lime plastering, but as they are more like cement than lime the hard plasters set instead of drying. The material should be mixed fresh every hour or two, only enough water being used to give it the proper consistency. No plaster that has partially set should be remixed.

119. Keene's cement.—*a.* When a highly polished and particularly hard white finish is desired, as in imitation tile wainscots in bathrooms, Keene's cement is used. It is generally applied to a foundation of portland cement mortar on metal lath, and where a tile effect is desired the surface is ruled off while soft with vertical and horizontal joints in tile size, and the wall is then given two coats of white lead and oil paint and a coat of white enamel.

b. This cement is also manufactured in a variety of attractive colors for use as a finish coat, and when colored cement is so used it is not customary to paint walls until they become dirty through usage. The recent development of this mill mixed colored cement has resulted in its wide use in quarters and other structures, and although the first cost is higher than white coat plaster the first painting cost is eliminated.

120. Other construction work.—The subjects of brickwork and plastering have been discussed somewhat in detail because such work is often performed by the Utilities Division. For a similar reason, the subject of concrete is discussed rather completely in chapter 4. While it would be of interest to take up other branches of the building trades, such as carpentry, roofing, painting, glazing, etc., it is not practicable to do so in a manual of this character. These are performed by experienced personnel at the post, camp, or station and generally consist of small repairs to existing works. Therefore, it will not be difficult to inspect the work done even though the utilities officer has not gone into these subjects exhaustively.

CHAPTER 4

CONCRETE

121. Definition.—Cement and water, mixed with an aggregate consisting of large and small particles, form an artificial stone which is called concrete.

122. Aggregate.—The aggregate is made up of fine and coarse particles, the fine particles being sand and the coarse being materials such as broken stone, slag. etc.

123. Design of concrete mixtures.—*a.* Concrete is a mixture of Portland cement, water, and inert materials put in place in a plastic

condition but hardening soon thereafter, due to the process known as the hydration of the cement. Although concrete is placed in a plastic condition and cannot be tested for quality at the time of fabrication, it is now practicable to produce concrete of any quality that may be necessary to meet requirements by proper control of the proportioning, making, and placing, and the subsequent curing.

b. The fundamental requirements of hardened concrete are strength, durability, and economy. Fresh concrete must be workable, that is, it must be of such consistency and physical make-up that it can be placed readily in the form without segregation of the materials and without requiring an excessive amount of spading to fill the form completely. Uniformity in both the fresh and hardened concrete is necessary to secure economy of materials, to facilitate handling and placing, and to obtain uniformity in the complete structure. It is particularly important where watertightness is required.

c. Most concrete is designed on the basis of compressive strength. However, the flexural and tensile strength, the bond with steel reinforcement, and the resistance to wear are, in general, governed by the same factors which govern the compressive strength. The compressive strength, therefore, may be used as an indication of these other qualities; and, since the test for compressive strength is comparatively simple, it is the test that is most often adopted.

d. If structures are to give long service, the durability of the materials is just as important as the strength. In much of the past practice this has not been fully appreciated, and too much emphasis has been placed on strength and economy alone. The most important factor affecting durability of exposed concrete is its watertightness. Durable concrete requires sound, durable aggregates thoroughly incorporated in a cement paste that is watertight.

e. While economy of materials is important, there are other factors affecting the economy of concrete which seldom receive proper consideration. The amount of labor required in placing and finishing concrete is a considerable item in the total cost. It can be reduced to a minimum by proportioning the materials to produce a plastic mixture which can be placed easily under the particular conditions of the job. The most economical concrete does not always result from the mix having the lowest cement factor nor the mix with the lowest cost for materials, but rather from the mix for which total cost—materials, handling, and placing—is the lowest.

f. The workability required will be different for different classes of work and will be determined by the methods of transporting and the details of placing, width and depth of forms, and spacing of

reinforcement. Plastic concrete may be regarded as a mass of aggregate particles, individually floated in a cement paste. This gives a mass that can be transported without segregation and can be placed easily in such a manner that when the forms are removed the hardened concrete will have smooth surfaces, free from honeycombing. Concrete of such consistency will require a minimum amount of finishing. In much of the practice in the past, such concrete has not been obtained. This was largely due to the fact that arbitrary mixtures were specified which did not permit adjustments in the mix to suit the character of materials, the condition in which they were measured, or the placing requirements of the job. In the endeavor to obtain workable mixtures, excess water was often added which almost invariably resulted in segregation, porosity, and low strength.

g. Uniformity is important since all parts of a structure designed for the same strength should be made of concrete of the same quality. Moreover, the greatest economy can be obtained only by the use of uniform batches of concrete. Uniformity is best secured by using plastic concrete made homogeneous by thorough mixing of uniformly measured quantities of materials, including the water.

h. The above fundamental requirements can be obtained by attention to each of the four major factors which determine concrete quality. These are the use of suitable materials, correct proportioning, careful methods of production, and protection during the curing period. Production methods, including measurement of quantities, mixing, transporting, placing, and curing, have an important influence on the quality of the finished concrete.

124. Effect of mixing water on strength.—As a result of extensive research in both laboratory and field, a method of proportioning has come into extensive use whereby the properties of the concrete can be predicted with considerable accuracy at the time of fabrication. This method is based on the relation that exists between the strength and other properties of concrete and the amount of mixing water used. The fundamental law has been well established and may be stated as follows: *For plastic mixes using sound aggregates, the strength and other desirable properties of concrete under given job conditions are governed by the net quantity of mixing water used per sack of cement.* The strength of concrete at a given age, therefore, will be determined by the amount of water used with each volume of cement, regardless of the quantities of aggregates used, so long as the mixture is plastic and workable, and the aggregates are clean and made up of sound particles. This principle may be more readily understood if the cement paste is thought of as a glue binding the aggregate particles

together. Increasing the water content dilutes the glue and reduces the strength. Not only is the compressive strength reduced by additional water, but the flexural and tensile strengths, the bond between steel and concrete, and the resistance to wear are reduced also.

125. Water cement ratio theory.—*a.* The water cement ratio theory is: That for given materials and conditions of manipulation, the strength of concrete is determined by the ratio of the volume of mixing water to the volume of cement (water ratio) so long as workable mixtures are obtained. In other words, if 1 cubic foot of water is used for each cubic foot of cement (water ratio of 1) in a concrete mixture, the strength at a given age is fixed regardless of the quantities of other materials used, so long as the mixture is plastic and workable and the aggregates are clean and made up of sound, durable particles. The amount of water is generally specified by the number of gallons per sack of cement with dry aggregates. The addition of excess mixing water serves only to dilute the paste and reduce the strength. Less than 2½ gallons of water is sufficient to hydrate one bag of cement. While it is necessary to use more than this amount to produce a workable mix of concrete, any water in excess of that required to hydrate the cement reduces the strength and makes a more porous concrete.

b. The quantity of cement, the plastic condition or workability of the concrete (whether it is wet or dry), and the size and grading of the aggregate affect the strength of concrete only insofar as they affect the quantity of water required in the mix. The important influence of these factors has long been recognized, but the part played by each was not clearly understood until their relation to the quantity of mixing water was demonstrated.

c. Tests made have demonstrated the accuracy of the water-cement ratio theory, and the three strength formulas given below will predict with sufficient accuracy for practical purposes the strength of concrete under the conditions stated.

(1) *Formula 1.*

$$\frac{S=27{,}000}{G}-1{,}600 \text{ or } G=\frac{27{,}000}{S+1{,}600}$$

S=Compressive strength of concrete at 28 days in pounds per square inch.

G=Gallons of water used per sack of cement.

This formula should be used only when the concrete is mixed under good job conditions; i. e., materials are accurately measured; the

amount of water per sack of cement carefully controlled; proper allowance made for moisture in the aggregate and the finished concrete cured in the presence of moisture.

(2) *Formula 2.*

$$S=\frac{24{,}000}{G}-1{,}600 \text{ or } G=\frac{24{,}000}{S+1{,}600}$$

This formula is similar to formula 1 above but assumes that job conditions are not as good, hence the resulting strength of the concrete is not as high. This situation is often found at Army posts where the size of the job will not warrant the expense of an inspector while the concrete is being mixed and placed.

(3) *Formula 3.*

$$S \text{ at 28 days}=S \text{ at 7 days}+30\sqrt{S \text{ at 7 days}}$$

This formula is very useful when it is desired to predict the strength of concrete at 28 days without waiting that length of time to find the result. For example, a test sample of concrete can be made up and set aside for 7 days. During this period the foundations and footings can be excavated. At the end of 7 days the sample is tested and the results are incorporated in formula 3. If satisfactory, the footings and foundation walls can be placed immediately. If it were not for this formula, which is quite accurate, it would be necessary to wait 28 days instead of 7 days to determine whether the concrete test sample was satisfactory.

126. Correction for moisture and absorption.—All aggregates as used under job conditions contain more or less moisture. Since this moisture becomes a part of the mixing water, the amount must be determined to make the proper correction in the quantity of water to be added to the batch.

127. Quantity of mixing water.—*a.* In calculating the amount of water, allowance must be made for moisture contained on the aggregate. This has been found to be seldom less than 2 percent and usually between 3 and 4 percent. This last is a safe figure to use except directly after a rain when 6 or 8 percent moisture should be allowed for. It is believed that these allowances will cover average construction conditions.

b. The amount of water on the aggregate for which allowance must be made can be determined by actual experiment. When tests for moisture on the aggregates cannot be made, approximate values given below may be used as a basis.

Approximate quantity of surface water carried by average aggregates (the coarser the aggregate the less free water it will carry):

	Gallons per cubic foot
Very wet sand	¾ to 1
Moderately wet sand	about ½
Moist sand	about ¼
Moist gravel or crushed rock	about ¼

128. Absorption of aggregates.—*a.* In correcting for moisture on the aggregate it is only the free or surface water that must be taken into account. When dry aggregates are used, allowance may be made for the absorption which takes place in the aggregate during the period of mixing and handling. For this purpose the absorption during a period of 30 minutes may be used. In the absence of tests, average quantities given below may be used as a basis.

Approximate absorption of aggregates:

	Percent by weight
Average sand	1.0
Pebbles and crushed limestone	1.0
Trap rock and granite	.5
Porous sandstone	7.0
Very light and porous aggregate (maximum)	25

b. Most aggregates used on a job are damp and contain more moisture than the equivalent of the absorption.

c. Various other factors, such as quality and size of aggregates, which enter into correct design of concrete mixture based on water-ratio theory are beyond the scope of this manual.

129. Effect of mixing water on durability.—The resistance of concrete to severe conditions of weather and to the action of sea and sulphate water is determined largely by the degree of impermeability or watertightness. While the influence of the water content of the paste on the watertightness of the concrete is not so well established experimentally as its influence on the strength, the relation is a fundamental one that is easily explained. During the process of hydration a certain amount of water combines chemically with the cement to become solid matter. The amount, however, is small, depending

upon the extent of curing, and is much less than the amount of water required to make plastic concrete. Water which does not enter into combination still remains distributed within the paste, and the space it occupies will be represented by air voids as the water evaporates. The more water used in mixing, the larger and more numerous will these air voids be, forming ready channels for the passage of water which may later be brought in contact with the concrete. A low water-cement ratio will produce a paste in which the voids are so minute and so well distributed that the paste will be watertight. Such a paste used with aggregate quantities to give a plastic homogenous mass will produce impervious concrete.

130. Selection of water-cement ratio.—The selection of a water-cement ratio as the basis for designing a concrete mixture involves a consideration of both the strength requirements and the degree of exposure to which the concrete is to be subjected.

131. Classes of concrete for different degrees of exposure.—*a.* The table below may be used as a guide in selecting the water-cement ratio where the conditions of exposure require a higher type of concrete than necessary to meet the strength requirements. Several types of structures are given in each group as suggestive; the exact classification in individual cases, or of other types, will depend upon the conditions of exposure at the particular site. The classification given is based on conditions prevailing in the greater part of the United States, and assumes proper workability of the mixture, thorough mixing, placing the concrete by puddling to fill the form completely and incorporate the reinforcement, and thorough protection from drying out or low temperature during the early hardening period.

b. In proportioning concrete for exposure, the water-cement ratios recommended in this table often result in concrete strengths that seem unnecessarily high. In order to assure concrete of the quality required to withstand the conditions of exposure, these water-cement ratios should not be exceeded. Perhaps the chief cause of unsatisfactory concrete in the past has been a tendency to rely on strength requirements alone in proportioning concrete for structures subjected to water pressure or severe weathering.

TABLE OF CLASSES OF CONCRETE FOR DIFFERENT DEGREES OF EXPOSURE

Type of structure	Degree of exposure	United States gallons of water per sack of cement [1]
Walls, dams, piers, and other structures exposed to sea or alkali waters.	Extreme	5½
Walls, dams, piers, reservoir linings, etc., exposed to alternate wetting and drying in fresh water in northern climate; watertight structures; sewers, pressure pipe, tanks, piles, athletic stadia, pavements; all thin structural members exposed to severe weather and frost action.	Severe	6
Walls, dams, piers, reservoir linings exposed to fresh water in southern climate; exterior columns and beams of reinforced concrete buildings; basement walls; thin structural members of all types exposed to moderate weather and frost action.	Moderate	6¾
Ordinary enclosed structural members; heavy piers and retaining walls in moderate exposure, pavement bases; mass concrete, footings, etc., protected from alternate wetting and drying and from severe weather conditions.	Protected	7½

[1] These quantities should not be exceeded even when resultant strength is higher than required for structural stability. Free water or moisture carried by the aggregate must be included as part of mixing water.

132. Selection of consistency.—The design of a concrete mix involves consideration of the requirements to be met in handling and placing the concrete and the factors affecting economy. In describing the character of fresh concrete, three terms are most often used—consistency, plasticity, and workability. "Consistency" is a general term relating to the state of fluidity of the mix and embraces the entire range of fluidity from the driest to the wettest possible mixtures. It requires a qualifying term for definiteness. The term "plasticity" is used to describe a consistency of concrete which can be readily molded but which permits the fresh concrete to change form slowly if the mold is removed. A plastic mass does not crumble but flows sluggishly without segregation. Thus, neither the very dry, crumbly mixes nor the very fluid, watery mixes are regarded as of plastic consistency. In this connection it may be pointed out that a low water-cement ratio does not necessarily mean a dry consistency.

133. Workability.—*a.* The term "workability" is used to describe

the ease or difficulty which may be encountered in placing the concrete in a particular location. The conditions under which the concrete is to be placed involve size and shape of the member, spacing of reinforcing rods, or other details interfering with the ready filling of the forms. It is obvious that a stiff plastic mixture with large aggregate, which is workable in a large open form, would not be workable, for example, in a thin wall of complicated reinforcing details.

b. There is little difficulty in arriving at a suitable mix with fixed proportions of cement and water, as this can be done by actual trial, making adjustments in the proportions until concrete of the desired character is obtained. The proportions of aggregate to cement for concrete of the water-cement ratios specified should be such as to produce concrete which can be puddled readily into the corners and angles of forms and around the reinforcement without excessive spading and without segregation or undue accumulation of water or laitance on the surface. In no case will concrete be placed which shows a slump outside the following limits:

Part of structure	Slump (inches)	
	Minimum	Maximum
Caissons	1	4
Heavy walls, slabs, and beams	3	6
Thin walls and columns	4	8
Pavements and foundations	1	3

It is desirable to reduce the proportion of water specified to a minimum that will give the workability desired.

c. To measure the "slump," the fresh concrete is placed in a metal frustrum of a cone with open ends 4 and 8 inches in diameter, respectively, and 12 inches apart. As soon as the cone is filled it is lifted off the floor and the concrete inside is allowed to slump down. The distance from the top of the cone, on the floor beside the concrete, to the top of concrete pile itself is called the slump.

134. Type mixtures of concrete.—*a.* Certain type mixtures are used by the Quartermaster Corps in construction work. The amount of water per sack is rigidly specified and the approximate amount of aggregates indicated. However, a variation in the amount of aggre-

gate is permissible so as to provide a dense concrete with the slump specified. These type mixtures are designated as follows:

(1) *Type A concrete* (for mass and plain concrete work).

Water—not to exceed 8¼ gallons per sack of cement.

Mix—1 part of Portland cement; 2½ parts of sand and 5 parts of coarse aggregate, size No. 4 to 1½ inches. Variations permitted in proportions of aggregate to provide a denser concrete of the required strength or workability.

Compressive strength—1,500 pounds per square inch after 28 days.

(2) *Type B concrete* (for reinforced concrete work).

Water—not to exceed 7½ gallons per sack of cement.

Mix—1 part of Portland cement; 2 parts of sand and 4 parts of coarse aggregate, size No. 4 to ¾ inch. Variations permitted as for type A concrete.

Compressive strength—1,100 pounds per square inch after 7 days and 2,000 pounds after 28 days.

b. For either type A or B concrete, the permissible sizes of coarse aggregate should be in such proportions that each size will fill the voids in the next larger size insofar as practicable, thus making a saving in the cost of cement and sand required.

135. Proportioning mixtures for quality.—It will be seen that the quality of concrete, so far as proportioning is concerned, is determined by the quality of the water-cement paste and that the relative amounts of aggregate and cement are important only insofar as they affect the workability and cost. Designing a concrete mix, therefore, consists in selecting the water-cement ratio which will produce concrete of the desired strength and resistance to exposure, and finding the most suitable combination of aggregates which will give the necessary workability when mixed with cement and water in this ratio.

136. Mixing.—*a. Machine mixing.*—(1) *General.*—The mixing of concrete, unless otherwise authorized, should be done in a batch mixer of approved type which will insure a uniform distribution of the materials throughout the mass, so that the mixture is uniform in color and is homogeneous. The entire contents of the drum should be discharged before recharging. The mixer should be cleaned at frequent intervals. The volume of the mixed material per batch should not exceed the manufacturer's rated capacity of the mixer.

(2) *Time of mixing.*—Each batch should be mixed not less than 1½ minutes after all the materials are in the mixer, during which time

the mixer should rotate at a peripheral speed of about 200 feet per minute.

b. Hand mixing.—When hand mixing is authorized, it should be done on a water-tight platform. The cement and fine aggregate should first be mixed dry until the whole is of a uniform color. The water and coarse aggregate should then be added and the entire mass turned at least three times or until a homogeneous mixture of the required consistency is obtained.

137. Unit of measure.—The unit of measure is the cubic foot. Ninety-four pounds of Portland cement (1 bag or 1/4 barrel) is considered 1 cubic foot.

138. Measurement of aggregates.—The method of measurement should be such as to secure the specified proportions in each batch. The aggregate should be measured separately by volume. In volume measurement the fine aggregate and the coarse aggregate should be measured loose, as thrown into the measuring device, and struck off. The water should be so measured as to insure the desired quantity in successive batches; it should be clean and fresh, and free from vegetable, sewage, or organic matter.

139. Retempering.—The retempering of concrete or mortar which has been allowed to stand longer than 30 minutes, that is, remixing with additional cement, aggregate, or water, must not be done. If it can be made workable by mixing or spading it is satisfactory.

140. Handling.—Concrete should be handled from the mixer to the place of final deposit as rapidly as practicable by methods which prevent the separation or loss of the ingredients. It should be deposited in the forms as nearly as practicable in the final position to avoid rehandling. It should be so deposited as to maintain, until the completion of the unit, a plastic surface approximately horizontal. Forms for walls or other thin sections of considerable height should be provided with openings or other devices that will permit the concrete to be placed in a manner that will avoid accumulations of hardened concrete on the forms or metal reinforcement. Under no circumstances should concrete that has partly hardened be deposited in the work.

141. Continued pouring.—When the concrete work is started, the pouring should be carried on continuously until an entire section is completed, the work being stopped at such a point as not to weaken the structure.

142. Compacting.—Concrete, during and immediately after depositing, should be thoroughly compacted by means of suitable tools.

The concrete should be thoroughly worked around the reinforcement, around embedded fixtures, and into the corners of the forms.

143. Protection.—Exposed surfaces of concrete should be protected from premature drying for a period of at least 7 days after being deposited.

144. Temperature of concrete.—Concrete when deposited should have a temperature of not less than 40° F. nor more than 120° F. In freezing weather, suitable means should be provided for maintaining the concrete at a temperature of at least 50° F. for not less than 72 hours after placing, or until the concrete has thoroughly hardened.

145. Pouring during hot weather.—All concrete placed during hot weather should be protected from the direct rays of the sun and air currents which cause too rapid drying. The exposed surfaces should be kept in a moist condition until the cement has set and the concrete has cured sufficiently.

146. Reinforced concrete.—Reinforced concrete is concrete in which steel is embedded in the form of rods, bars, shapes, or netting, so united that the concrete takes the compression while the steel takes the tension and assists in resistance to shear. The metal used with the concrete is called reinforcement. When used as reinforcement, wire-mesh fabric should be woven or electrically welded fabric of cold-drawn mild steel.

147. Distribution of stresses.—The term "reinforced concrete" does not apply to those combinations of steel and concrete in which the steel is designed to support all the loads. In these combinations the concrete simply protects the steel from corrosion and fire, and the steel is designed to support the concrete as well as the other loads. In reinforced concrete, on the contrary, the proportions of steel and concrete are so designed that the stresses will be distributed properly between the two materials.

148. Object of reinforcement.—Concrete structures are used principally because of their rigidity and durability. The primary object of the reinforcement is to reduce the cost of the structure. Concrete has a low tensile strength, and the amount that would be required in structures subjected to tension would be very large. It is, therefore, more economical to use steel to resist tensile stresses. On the other hand, the compressive strength of concrete is comparatively high, and in many cases it is cheaper to use this material to resist compressive stresses. Hence, a very economical structure can be obtained by combining the two materials and so designing the structure that the compressive stresses will be resisted by the concrete and the

tensile stresses by the steel. This is the principle on which reinforced concrete construction is based.

149. Columns.—Concrete members that resist compression only, such as columns and piles, are commonly reinforced with steel, since it has been found that they can better withstand the effects of shocks than when not reinforced. In some cases the steel assists in resisting the compression, in others it simply serves to hold the concrete together in such a way that it can withstand greater stresses.

150. High early strength concrete.—It is often desirable to produce concrete having comparatively high strength a few days after it has been placed so that it can be put into use at the earliest possible moment. High early strength can be made with standard Portland cement. Since the important factors which govern the strength of Portland cement concrete are the relative proportions of cement and mixing water, time of mixing, and conditions during curing, these factors may be adjusted to produce concrete of the desired strength at an early age. Sometimes an accelerating admixture may be used to increase further the rate at which the concrete develops its early strength. This method, however, has not been found to be dependable, and today most large producers of Portland cement manufacture a special "high early strength" cement whose characteristics have been well tested and whose action in concrete aggregates can be reasonably well predicted.

151. Compressive strength.—In a test made using 5 gallons of water per bag of cement, with a 2-percent calcium chloride admixture, a concrete was produced which had a compressive strength in excess of 2,500 pounds per square inch in 48 hours. Concrete as commonly used, with proportions of cement and aggregate, quantity of mixing water and mixing time as ordinarily used for type B concrete, has a strength of about 2,000 pounds in 28 days. A strength of 2,000 pounds or more in 3 days is obtained with the same materials and the same cement by applying the following well-established methods:

a. Decrease the amount of water.

b. Increase the amount of cement (without adding any water).

c. Increase the mixing time (never less than 1 minute, additional time up to 5 minutes is still better).

d. Place concrete at a temperature of at least 70° F.

e. Keep concrete at a temperature of at least 70° F. for 3 days.

f. Keep concrete damp for 3 days.

152. Forms.—To a certain extent the strength and especially the appearance of concrete is dependent on the strength and workmanship of the forms. Wood forms are usually used, but when the pouring

loads are heavy, or where the supported spans are long, or the forms are simple in construction and are to be reused an unusual number of times, metal forms have been found more satisfactory. Concrete forms must be watertight to prevent leakage with resulting "honeycomb"; with smooth surfaces to guarantee good appearance without excessive rubbing; and absolutely rigid to prevent movement in any direction during pouring and the time required for the concrete to acquire its set. Lining of regular wood forms for exposed concrete surfaces with plywood with close-fitted joints eliminates excessive rubbing and prevents leakage. Under normal weather conditions, wall and column forms may be stripped in 48 hours and slabs in from 10 to 14 days.

153. Hollow tile concrete floors.—For lighter floor live loads in buildings, a combination hollow tile, clay or metal pan, has been found economical. The concrete in the lower portion of the slab is partially replaced by tile or pans, the concrete being poured in the form of a T-beam between rows of tile. Where a finished ceiling is required, however, a metal lath plastered ceiling has to be added which eliminates part but not all of the original saving.

154. Cost of concrete.—Data upon the cost of concrete, i. e., amounts of cement, aggregates, labor factors, etc., are given in chapter 5.

155. Additional reading.—The above discussion upon the water-cement ratio for concrete mixtures has been given only in sufficient detail to enable a utilities officer to carry out field supervision. The subject of "Design and control of concrete mixtures" is developed in detail in a pamphlet of the same name issued by the Portland Cement Association.

CHAPTER 5

ESTIMATING MINOR CONSTRUCTION, REPAIRS, AND MAINTENANCE COSTS

SECTION I

ESTIMATING BRICKWORK AND CONCRETE COSTS

156. General.—*a.* Of the various technical duties devolving upon the utilities officer, none is more important than that concerned with the preparation of accurate estimates of the cost of new construction work or of repair work. Before commencing any important piece of work, it is necessary to ascertain as closely as practicable its probable cost in order to make certain that funds will be available for the work. Very often a commanding officer will ask if the funds available are sufficient to perform certain work, and a definite answer can be given only after an estimate of cost has been made.

b. It is not practicable in this manual to discuss the preparation of estimates for work involving all the building trades. However, data are provided which will permit the student to prepare estimates for the more common types of brickwork and concrete. Estimates for other building trades are prepared in a similar manner.

157. Cost of construction work.—The cost of construction work is made up of four major elements: cost of materials, cost of labor, overhead and, if done by contract, a profit.

a. Cost of materials.—The cost of materials is found by breaking down the work to be done by each building trade into its component elements. For instance, the cost of materials in a brick wall would be found by computing the total cubic feet of brickwork and then using the data in paragraph 159, ascertaining the number of brick, the amount of Portland cement, sand, hydrated lime, etc., required to construct the wall. Having determined the amount of materials required,

it is a simple matter to get bids from material dealers in order to determine the cost of materials.

b. Cost of labor.—In addition to the cost of materials in a piece of work, it is necessary to estimate the cost of labor to install the materials. The amount of labor (man-hours) for any class of work is determined by consulting records of previous similar work. For instance, on a previous job it has been found that it takes 16 man-hours of a bricklayer's time and 13 man-hours' time of a bricklayer's helper to lay 1,000 bricks, American bond, in a 12-inch brick wall. Therefore, knowing the number of thousands of bricks to be laid in a similar wall, it is simple to estimate the number of man-hours of labor required for the entire job for each class of labor. Applying the labor rates per hour for each class of labor, the total cost of labor will be obtained.

c. Overhead.—In addition to the cost of labor and cost of materials, it is necessary to provide for the overhead expense which includes salaries of superintendents, timekeepers, clerks, insurances, rental and wear of equipment, etc., and any other items of expense that are chargeable to the job and not covered by the cost of direct labor and materials. This item of overhead is generally covered by adding to the cost of direct labor and materials a certain percentage which past experience on other jobs has indicated.

d. Profit.—If it is the intention to have the work done by contract, it is necessary to add to the cost of labor, cost of materials, and cost of overhead, an additional percentage representing a fair profit to the contractor. However, the majority of repair jobs done by the utilities officer at a post, camp, or station will be done by the purchase and hire methods, in which case the provision for a profit will be unnecessary in the estimate. It will be found frequently that if post costs of labor and material are used in preparing an estimate for moderately large jobs which are to be done by contract, no contractor's profit need be added to those costs. The contractor's price, including profit, will usually be less on account of his specially trained organization and more experienced supervision.

158. Estimating data.—In paragraphs 159 to 161, inclusive, there are set forth certain useful data in connection with brickwork, concrete work, and painting at Army posts. These data, while not complete, illustrate the method of preparing estimates so that the results will be reasonably accurate. It must be appreciated that an estimate is only a scientific guess as to what the final cost will be

when the job is completed. Other estimating data can be found in many books on the market, such as The Building Estimator's Reference Book, by Frank R. Walker, and cost records of many classes of work may be found at each post, camp, and station.

159. Cost of brickwork.—To ascertain the cost of a proposed piece of brickwork it is necessary to take the following steps:

a. Materials.—First step.—Compute the total cubic feet of brickwork to be built and multiply by the total brick per cubic foot as shown in table I below, using the desired thickness of the joints in the brickwork. The result will be the total brick (face and common) that will be required.

Second step.—Compute the total number of square feet of surface to be covered by face brick and multiply by the total face brick (all stretchers) as shown in table I, and the result will be the number of face brick required, without provision for the bond. The percentage to be added for bond is indicated in this table.

Third step.—From the total brick found by the first step subtract the number of face brick found in the second step, and the remainder will be the number of common brick required.

Fourth step.—From table I find the amount of mortar required to lay 1,000 brick with the required thickness of joint. Referring to the column headed by the required amount of mortar, each factor must be multiplied by the total brick (face and common) to find the amount of cement, sand, and lime necessary to lay the brick.

Fifth step.—Having found the quantities of face and common brick and the amount of cement, sand, and lime, it is a simple matter to apply the current unit prices to these quantities and arrive at the estimated cost of all materials required for the piece of brick masonry.

TABLE I.—*Brickwork; materials. Amount of brick and mortar*

Thickness of joint (inches)	Number of face brick per square foot (all stretchers)	Number of brick per cubic foot	Cubic yards mortar per 1,000 brick	Remarks
⅜	[1] 6⅔	20	0.50	Based upon brick size, 2¼ by 3 to ¾ by 8 inches.
½	[1] 6⅓	19	.60	
⅝	[1] 6 1/12	18¼	.70	

[1] Add for headers: 16⅔ percent for American bond; 33 percent for Flemish bond; 50 percent for English bond.

Ingredients in mortar for 1,000 bricks

Mix of mortar	Ingredients	0.50 cu. yd.	0.60 cu. yd.	0.70 cu. yd.
1 part	Cement	1.15 bbl	1.35 bbl	1.60 bbl.
3 parts	Sand	0.50 cu. yd.	0.60 cu. yd.	0.70 cu. yd.
10 percent of weight of cement.	Lime	20 lbs	24 lbs	28 lbs.
1 part	Cement	0.50 bbl	0.70 bbl	0.80 bbl.
1 part	Lime	98 lbs	120 lbs	140 lbs.
6 parts	Sand	0.50 cu. yd.	0.60 cu. yd.	0.70 cu. yd.

NOTE.—Acid (muriatic) to clean brickwork amounts to 1 pound per 100 square feet of wall facing.

b. Labor.—Various factors affect the cost of labor in laying face brick, such as type of joint in finished surfaces, kind of face brick (rough or smooth), etc. It is then a simple matter to apply the factors given in table II to the amounts of face and common brick found as prescribed in paragraph 159*a* in order to find the man-hours of labor for the bricklayer and for the helper. The man-hours of labor multiplied by the prevailing wage rate will give the estimated cost of labor for this piece of brick masonry. When computing the cost of cleaning face brick do not include the number of face brick allowed for the bond.

TABLE II.—*Brickwork; labor factors*

Common brick	To lay 1,000 brick	
	Mason (hours)	Helper (hours)
Foundation walls—Interior partitions	8	8
Backing up face brick with common brick	9	9
Face brick:		
American bond—		
Flush cut joint	16	13
Tooled joint	17	13
Weathered joint	18	13
Flemish bond—		
Flush cut joint	18	13
Tooled joint	19	13
Weathered joint	20	13
Cleaning brickwork (rough brick) with acid, including repointing where necessary	[1] 1	--------
Cleaning brickwork (smooth brick), etc	[1] 0.5	--------
Sorting common brickwork to select best for facing	--------	2

[1] Per 100 square feet of face brick surface.

All mortar will be mixed by the bricklayer's helper, and the required labor for mixing it has been provided for in the above labor factors for the helper.

160. Cost of concrete, cement mortar, etc.—The cost of concrete is made up of the costs for cement, sand, coarse aggregate, the cost of labor for placing, as well as the cost of the incidental form work.

a. Materials.—First step.—Compute the number of cubic yards of each type of concrete and the number of cubic yards of cement mortar of each kind of mix required. Also determine the number of square feet of concrete that will be in contact with the concrete forms, segregating horizontal and vertical surfaces.

Second step.—Apply the data found by the first step to the factors in table III, and the result will give the required quantities of Portland cement, sand for concrete, sand for cement mortar, coarse aggregate, and lumber for form work.

Third step.—Extend the quantities found in the second step by applying current unit prices for these materials, and the totals will be the cost of materials for the concrete work in question.

TABLE III.—*Materials; concrete, mortar, and forms*

Ingredients in 1 cubic yard of concrete

Proportions by volume	1:2:4	1:2½:5	1:3:6
Portland cement ---------- barrels	1. 46	1. 13	1. 05
Sand ---------- cubic yards	. 41	. 40	. 44
Broken stone or gravel ---------- do	. 82	. 80	. 88

Ingredients in 1 cubic yard of cement mortar

Mix	Cement (barrels)	Sand (cubic yards)
1 to 1	5. 0	0. 70
1 to 1½	4. 0	. 84
1 to 2	3. 33	. 93
1 to 3	2. 25	1. 00

Number of board feet per contact foot of concrete

Form work	Amount of material
For small walls and columns.	2 board feet of lumber for each square foot exposed wall surface in contact with forms.
For reinforced concrete floors.	3.5 board feet lumber per square foot exposed under surface of slab in contact with forms.

b. Labor.—Having determined the amounts of concrete and mortar and the areas of finished surfaces, it is not difficult to estimate the amount of labor of the various kinds which will be required since the factors given in table IV will cover most of the concrete work done by a utilities officer. The total man-hours of labor of the various kinds multiplied by the prevailing wage rates will give the labor cost of the project.

TABLE IV.—*Labor factors; concrete, mortar, and forms*

Labor	Time
Mixing concrete by hand	6 man-hours common labor per cubic yard concrete including transportation of the concrete up to 50 feet.
Mixing concrete by small 1-bag mixer.	3.5 man-hours common labor per cubic yard concrete including transportation of the concrete up to 50 feet.
Mixing, placing, and finishing 100 square feet of cement floor topping.	2.5 man-hours for cement finisher. 1 man-hour for finisher's helper. (Includes mixing of mortar.)
Placing 100 pounds of steel reinforcement.	1.5 man-hours for steel worker.
Placing 100 square feet of steel mesh reinforcement.	0.4 man-hour for steel worker.
Placing and removing forms.	1 man-hour carpenter per 10 square feet of floor and wall surfaces in contact with forms; 1 man-hour carpenter for 5 square feet for column surfaces in contact with forms.

SECTION II

ESTIMATING PAINTING COSTS

161. Cost of painting.—*a. Rules for measurement of painting.*—In present-day practice, areas to be painted are figured in squares (100 square feet each). As a general rule, the actual areas of painted surface should be measured, but, in addition, there are a few special rules used for certain conditions.

(1) *Clap boarded walls.*—Take the actual area and add 10 percent to take care of the under edge of the board.

(2) *Cornices.*—Take the actual girth of the cornice and multiply it by the length.

(3) *Door frames.*—Take actual girth of frames and multiply it by the length.

(4) *Mouldings.*—If under 6-inch girth, call it 6 inches wide and

multiply by length. Wood base under 1 foot high should be figured as 12 inches wide.

(5) *Window frames and sash.*—Take neat opening to measure exterior painting and make no deductions for the glass. Take neat opening to measure interior painting, make no deductions for glass, and add 15 square feet to take care of trim.

(6) *Interior door* (frames and door).—For ordinary size doors, up to 3 feet wide and 7 feet high, allow 40 superficial feet for each side of the door.

(7) *Walls, interior and exterior.*—Deduct neat opening of windows and deduct neat opening of doors from the gross area of walls. All dimensions are to be to the nearest foot.

b. Cost of materials.—Using the method described in *a* above to determine the area to be painted, it is only necessary to use the proper factors in table V below to arrive at the amount of paint required, and by applying the correct unit costs of such paints the cost of painting materials may be secured.

TABLE V.—*Covering capacity of 1 gallon of various kinds of paint*

Kinds of paint	Square feet
Lead and oil:	
Priming coat on wood	400
2-coat work on wood primed	240
3-coat work on wood primed	160
Single coat after third on wood	500
Cold water paint—1 pound covers one coat	30
Calcimine—1 pound covers one coat	50
Lead and oil:	
2-coat work on sized plaster	275
3-coat work on sized plaster	200
Additional coat over third on sized plaster	550
Paste filler for hardwood floors—2½ pounds	100
Wax for floors:	
1 pound paste wax	250
1 gallon liquid wax	500
Varnish:	
1-coat, hardwood floor	500
1-coat, softwood floor	400
Red lead and oil, on metal—1 coat	600
Radiator enamel—1-coat on metal	500

NOTE.—The above figures are safe approximations. Experienced painters can increase the covering capacities by 10 percent.

c. Cost of labor.—Having determined the areas to be painted, it is only necessary to use the proper factors in table VI to arrive at the amount of labor necessary to apply the paint. The amount of labor

multiplied by the prevailing labor rates determines the cost of labor for painting.

TABLE VI.—*Labor factors; painting (1 hour's work)*

Kind of paint and type of surface	Method	Area (square feet)
Priming coat on wood	By hand	150
Two-coat work on primed wood	do	60
Three-coat work on primed wood	do	40
Each additional coat on wood	do	150
Cold water paint, one coat on plaster	do	150
	By machine	300
Calcimine, one coat on plaster	By hand	150
One coat shellac and two coats varnish	do	30
Paste filler	do	125
One coat on steel	do	150
Two coats on steel	do	75

UTILITIES

CHAPTER 6

HIGHWAY CONSTRUCTION

162. Roads on military reservations.—The road systems under control of the Quartermaster Corps are largely confined to military reservations but usually present such diversity of conditions that it is necessary to give consideration to the methods of road construction in order best to meet the many problems of construction and maintenance.

163. Mileage of roads.—*a.* It is estimated that the Quartermaster Corps is responsible for the maintenance of approximately 1,600 to 1,700 miles of roads. The mileage of improved roads is divided among the various types of road construction approximately as follows:

	Miles
Water-bound macadam	181
Bituminous macadam	308
Gravel	238
Concrete	330
Cinder and shell	32
Brick	341
Miscellaneous, slag, brick, stone block, etc	215

b. It is obvious, therefore, that quartermasters should study the principal phases of highway construction and maintenance as well as highway transportation and traffic control.

164. Development of automobiles.—The development of the automobile and its rapidly increasing use for different purposes have revolutionized road and pavement construction both in cities and in country districts. The added important factors to be dealt with as a result of this development are chiefly the effects of high speed and the greater weight of vehicles. These result in higher requirements for smoothness of surface, greater strength of surfacing to distribute effectually the loads over the soil, and greater resistance to the disintegrating effect of traffic on roads.

165. Traffic requirements.—*a.* Natural soil roads and those which were slightly improved by a thin surfacing of gravel, crushed rock, slag, cinders, or shells were usually satisfactory for light animal-drawn vehicular traffic, but the motor vehicular traffic has so changed conditions that all important roads are now required to be paved

with stronger and more durable material, such as cement, concrete, or asphalt or tar-bound macadam.

b. The development of modern roads and pavements has been largely influenced by the characteristics of the newer types of vehicles. Because of higher speed, pavements need to be wider, smoother, have better alinement, gradients, and less convexity of surface. Surface requirements are essential, but good drainage and firm foundations are also of great importance. Therefore roads should be built not only to meet the requirements of traffic but also with due consideration for soil conditions.

166. Estimate of traffic.—In the design of a road pavement, consideration should first be given to the estimate of probable traffic requirements. It is very important to estimate the probable increase in traffic to which the road will be subjected. This increase might result from a diversion of traffic from other roads which are parrallel to it or lead in the same general direction as the road in question. It should always be borne in mind that a good road attracts traffic.

167. Factors in determining types of roads.—In view of the rapid development of motor traffic, permitting greatly increased wheel loadings, speed, and volume of traffic, it is found that the tendency in road construction is toward the more permanent types wherever funds for such construction can be secured. Where traffic conditions warrant, concrete pavement or some form of improved macadam should be used. It will still be necessary to utilize the cheaper types of roadway, such as gravel and sand-clay roads or light asphalt or tar-treated surfaces where the more enduring types are not warranted. The conditions which justify the construction of the more permanent types of roadway are volume of traffic, weight and loading of vehicles, extent and importance of territory served, and directness of route, this latter being an important factor as it greatly influences the probable increase in traffic after improvement in roadway has been made.

168. Location of routes.—*a*. It may be assumed that the major part of new road work in military posts will be built over present existing routes, with possibly some modifications in grade, alinement, and width, so that it will not be necessary to be concerned with the problem of location in such instances. It is possible, however, that entirely new construction may be necessary, in which event there are certain factors which are of importance in determining the proper route to be chosen. These are—

(1) Selection of the most direct route which will serve all or at least the most important points requiring service.

(2) Avoidance of sharp curves and excessive grades.

(3) Well-balanced cut and fill.

(4) Proper drainage.

b. In selecting the most direct route, it is not intended that a straight line must be chosen; but the route should be as direct as possible, and at the same time advantage should be taken of the natural topographical conditions in order that excessive construction costs may be eliminated.

169. Clear sights.—In general, there should be clear sights of at least 400 feet around curves, so that the driver of a motor vehicle can see another vehicle traveling in the same or opposite direction, and have sufficient distance in which to bring his vehicle to a stop if necessary. Clearing away the brush and small growth at the sides of the road or removing a wall or a fence will frequently accomplish the object sought. Where the bank on the inside of the curve is much above the grade of the road and the curve is very sharp, it may be necessary to cut into the side of the bank at a height equal to the average line of vision of the persons on the road when driving.

170. Approaches to bridges, etc.—Approaches to bridges and underpasses should be as straight as possible for a considerable distance beyond each entrance, and abrupt grade changes at these points should be avoided. The inside faces of the side walls or parapets of a bridge should be at least 3 feet from the edges of the road, otherwise vehicles will tend to keep away from the abutments and move toward the center of the road making collisions with other vehicles more likely.

171. Location near buildings.—Roads should never be located so near buildings that there is insufficient room for side ditches or gutters.

172. Life of roads.—Some of the important factors which have a direct effect on the length of life of road pavements are—

a. Smoothness of surface.

b. Foundation soil or subgrade.

c. Drainage—surface and subsoil.

d. Climatic conditions.

173. Temporary roads in emergency construction.—The manner in which road construction is handled at mobilization camps or any emergency establishment is of very great importance. The ideal solution of the problem would be to construct all important roads in advance of the beginning of all other construction work, but this cannot be done because such an arrangement would too greatly delay the completion of the project. It is therefore considered the best practice to construct, in advance of other construction, sand-clay,

gravel, or slag roads as temporary roads. These can be used as construction roads and later converted into permanent roads or used as the foundation for pavements where such are required. The work on the more permanent form of road construction should not be done during the rush work on buildings and utilities.

174. Resistance to traction.—*a.* The amount of tractive force which is required to be exerted upon a vehicle to maintain any given rate of speed is equal to the sum of all resisting forces. These resistances are axle friction, rolling resistances, gradient resistance, and air resistance. The combination of these road resistances is designated by the general term "resistance to traction."

b. Axle resistance varies widely with different bearings. It also varies directly with the load on the wheels.

c. The rolling resistance varies with different types of vehicles and different kinds of road surfaces. It depends largely upon the diameter of the wheels, the widths of tires, speed of vehicle, and condition of the wearing surface of the road. Large wheels offer less resistance than wheels of small diameter, and broad tires generally less than narrow ones.

d. The resistance offered by the roadway to rolling of wheels is occasioned by want of uniformity in road surface or lack of strength to resist penetrating efforts of loaded wheels. Rolling resistance is also considerably affected by curves; the sharper curves offering greater resistance than long-radius curves.

e. Gradient resistance is the additional force required to raise a vehicle above a certain level. This force, which must be added to the rolling resistance, increases directly with the inclination or percent of gradient.

f. The factors of real importance, or those most directly related to road construction, are rolling resistance and gradient resistance. Axle resistance is of little importance and air resistance is not a controlling factor.

175. Grade.—*a. Percent of grade.*—The percent of grade of a road is the rate of change in elevation for each 100 feet. For example, if the difference in elevation of two points on a roadway is 15 feet, and the points are 300 feet apart, the rate of change in elevation in 100 feet is 5 feet, and the grade is designated as a 5-percent grade. However, if there is a change of 5 feet in 25 feet of roadway, the grade is designated as a 20-percent grade.

b. Maximum grade.—Important improved roads should not be constructed with any considerable length of grade exceeding 5 percent, although there may be exceptional conditions where this grade would

have to be exceeded. On less important roads, maximum grades of 8 percent may be permitted. It must be understood that these maximum grades should extend for short distances only. As a rule there will always be cases where the maximum gradient adopted as a standard cannot be maintained and exceptions will have to be made. In such instances the best gradient consistent with conditions must be adopted. The maximum grade limits the speed and vehicle loads. Where automobile traffic prevails and exceptional conditions exist, as in mountainous country, grades may be 8 to 12 percent for short distances.

c. Minimum grade.—It is inadvisable to construct a road of any considerable length without longitudinal slope. At least a slight inclination should be provided in order that proper drainage may be secured. Roads located on embankments may be level longitudinally because the cross slopes of a road provide for adequate drainage. As a general rule, the smoother the surface of a pavement, the lower the degree of gradient which can be considered the minimum. A gradient of ½ of 1 percent is usually regarded as a minimum to provide proper drainage.

176. Gradient on curves.—The maximum gradients on curves should be smaller than on tangents.

177. Tangents.—Straight lines of roads are designated as tangents. The ideal road is one constructed with long, straight lines connected where change in direction is necessary by circular curves with as long radius or as flat curvature as possible. It is especially important in these days of high-speed traffic that the alinement of a road be as free as possible from sharp curves.

178. Width of roads.—*a.* The width of roads should be governed by the number of lines of traffic which must be accommodated and the speed at which they move, more clearance being required for traffic moving at high speed. The 5-ton truck used by the Army has over-all dimensions of 7 feet 6 inches by 21 feet. Trucks of these large dimensions require at least 2 feet 6 inches for clearance at a speed of 12 miles per hour, which fixes the widths of roadway for this kind of traffic at not less than 20 feet.

b. Where light automobiles or mule teams constitute a large percentage of the traffic, and where the width of vehicles is not above 6 feet 3 inches, a width of roadway of 18 feet is sufficient. Widths less than 18 feet should not be used unless traffic is light, slow-moving, and the roadway constructed with substantial shoulders of bituminous or water-bound macadam; the consideration being that any light-traffic

roadway may suddenly be used by heavy traffic as a detour or because of a change in conditions.

179. Width at curves.—At all curves of less radius than 400 feet, the width of pavement should be increased from 2 to 4 feet or more on the inside of the curve to provide additional clearance.

180. Crown.—The crown is the rise in cross section from the lowest to the highest part of the finished roadway. It may be expressed either as so many inches (or tenths of a foot) or as a rate per foot of distance from side to center, that is, "the crown is 4 inches," or "the crown is ½ inch to the foot."

181. Cross section on tangents.—On tangents the cross section of a road should be identical on either side of the center line.

182. Cross-section profile.—The degree of slope varies inversely with the compactness and smoothness of the road surface. For illustration, a water-bound macadam or gravel road having a width of 18 feet should have a crown height of approximately 3½ inches, and a concrete road of the same width should have a crown height of approximately 2 inches.

183. Superelevation.—*a.* The road surface at curves should slope from the outside of the roadway toward the inside. This change in elevation between the inside and outside of a road on a curve is called the superelevation, and the amount of difference is dependent upon the sharpness of the curve and rate of speed permitted. The amount of superelevation to be provided is determined from the formula—

$$E=0.067\frac{V^2}{R}$$

where

E=maximum elevation in feet per foot of width.
V=velocity in miles per hour.
R=radius of curve in feet.

b. Superelevated or banked curves as they are usually called should be used on all roads of the better class.

184. Subgrade.—The finished surface on which the road material is laid is called the subgrade. It is prepared either in cut or on fill or if the road is constructed over an existing roadbed it is the graded surface of the old road.

185. Excavating for subgrade.—In general on a new location, excavation should conform to the subgrade and side slope lines, and all material not suitable for foundation or subgrade should be removed even though it may be necessary to go below finished sub-

the existing surface and remove surface material to a depth which will insure an even wearing surface, the excavated material being used to construct the necessary shoulders.

194. Destructive effects of water.—Water is one of the most destructive influences on the surface of earth, gravel, and broken-stone roads. When it collects and stands, mudholes are formed, the road material becomes softened, and traffic rapidly increases the size of the mudholes, until finally the hard surface or crust of the road is broken through and very rapid deterioration follows. If water is allowed to collect in side ditches, it percolates sidewise under the roadbed, softening the subgrade and ultimately causing subsidence of road surface. Water once under a roadway and subjected to freezing weather will eventually destroy the roadbed. It is, therefore, important that subgrades in wet country be properly drained and surface of roads kept in such condition that drainage direct to side ditches can be obtained.

195. Expansion and contraction in subsoil.—Pavements may be injured by the expansion and contraction of the subsoil owing to freezing and thawing (heaving action) and also in some cases to wetting and drying of the soil. All clayey soils are subject to heaving action in cold climates. Gumbo and adobe are especially objectionable for subgrade material because of their change of volume with varying degrees of moisture.

196. Elevation of subgrade.—In dealing with subsoil problems in soils of the class referred to in paragraph 195, it is of great importance to form the subgrade of the road at a higher elevation than the flow line of the side drainage ditches. It is a mistake to construct a pavement in a trench where the soil is dense or the natural drainage is poor. Under such conditions, it is far better to use a porous material for the subgrade and place it on the original soil or even on an embankment. Therefore, as a rule, roadways should not be constructed in trenched-out beds but should be built on earth fill or natural soil so that the subgrade is above the surrounding terrain.

197. Granular soils.—Soils of a granular nature such as cinders, sand, and gravel are more desirable subgrade materials than clayey soils as they drain very readily, retain little water, and do not change in volume appreciably.

198. Subsoil drainage.—*a. Construction.*—Proper subsoil drainage of roadbeds is considered by many engineers the most important factor in good road construction. Drainage of the sub-

grade is accomplished by the use of tile laid below the ditch at the side of the road, with carefully constructed outlets, or by the use of trenches filled with clear gravel or broken stone. Subsurface drains should not carry any surface water; it should be taken care of by the side ditches.

b. Sidehills and cuts.—(1) On sidehill locations and cuts, the underground water may be removed by the use of side subsoil drains. These are usually formed by trenching to a depth of about 3 feet, the bottom width of trench being about 12 inches and top width 15 inches. The bottom of the trench should slope uniformly to points where proper outlets are made. A slope of 3 inches per hundred feet is sufficient but may be exceeded. Tile drain is laid in the bottom of the trench. The joints of the pipes should be wrapped with cloth or other equally effective material so as to exclude solid matter from the interior of pipe. This line is then covered to a depth of about 1 foot with broken stone or crushed gravel. The remainder of the trench should be filled with whatever porous material or soil is available.

(2) These drains are not effective unless free outlets are maintained. Drains should always be ample in size to take care of maximum flow.

199. Control of surface drainage.—Surface drainage should be controlled so as to prevent, as far as possible, injury to road surface, shoulders, and foundations resulting from the erosive action of the water. Swift currents cause rapid erosion of earth gutters or ditches; the greater the volume of flow the greater the erosive action. Many pavements and roads have been destroyed by the erosive action of water in ditches and gutters. The remedy for this condition is either more outlets for ditches or a combination of more outlets and paving of ditches.

200. Side ditches.—Side ditches should be wide and as shallow as possible to insure sufficient fall. Narrow, deep ditches have the disadvantage of being easily obstructed by caving sides and are dangerous to traffic, which may be forced to the side of the road.

201. Drainage on steep grades.—*a.* Where surface drainage ditches are constructed on steep grades, care should be taken to prevent excessive erosion, especially at points of excessive change in grade and at points of change in direction. The points at which erosion is most apt to occur should be protected by stone paving or concrete or rock diversion walls. Slopes of earth ditches for short distances, when small quantities of water are carried, may be 5 percent

and those of sand 3 percent, without providing lining such as cobble stones, coarse gravel, etc. Ditches over long distances must be paved.

b. On sidehills, surface water should be collected by ditches on the uphill side and carried across the road to downhill side through suitable culverts.

202. Obstructions in water courses.—All water courses which receive drainage water from roads or ground adjacent to roads should be maintained free from obstructions. Otherwise, the water will be held at levels interfering with the stability of the foundation beds of the roads.

203. Capacity of culverts.—Unless culverts have sufficient carrying capacity they will form temporary barriers to the drainage water. A ditch without a free outlet is worse than none.

204. Wearing material and binder.—The wearing surface of improved roads is composed of two classes of material, the wearing material and the binder. This generalization is true with reference to all modern types of road surfacings or pavements.

a. Wearing material.—The wearing materials are the particles of sand or stone in sand-clay, gravel, macadam, and concrete roads that resist the crushing and abrasive effects of traffic.

b. Binder.—A binder is a fine material such as clay, cement, or bitumen introduced into the wearing course for the purpose of binding together the particles of the road material and for assisting particles to resist separation under stress. A second function of the binder is to resist the penetration of moisture.

205. Materials.—The materials most commonly used in road construction are sand, gravel, or crushed stone, cement, mixtures of clay and gravel, and earth; also a natural asphalt, oil asphalt, or tar, used as a binder where bituminous macadam is laid.

206. Maintenance.—It is well to bear in mind that all types of roads require maintenance and repair, and in all cases timely maintenance will prevent excessive repair costs.

207. Sand-clay roads.—*a.* Dirt and sand-clay roads are economically kept in a state of good repair a major part of the year by dragging and the proper care of ditches. Defects should be remedied as soon as they appear, because once started they develop rapidly. These roads are more easily repaired than others because suitable material is always available on the surface with which ruts and hollows can be scraped full. Dragging and scraping the surface is performed best after rains, when the material has dried sufficiently to

permit consolidation and packing of the road material so that new ruts are not easily formed by traffic.

b. Maintenance of earth roads will be facilitated by frequent use of roller, grading, and scraping machines.

208. Gravel roads.—*a.* General repairs to gravel roads are made preferably in the spring of the year when the entire surface is so softened that material moved from sides to center or from high to low places by scrapers will be readily bonded where it falls. Scraper blades should be set diagonally to the road, so that a sideway cutting and moving effect will be secured.

b. Unlike dirt and sand-clay roads, grading can be done well during dry weather if water is applied. All material thrown out by traffic should be moved toward the center to assist in filling depressions. All material so moved may not and probably will not consolidate but enough will do so to warrant the work.

c. It is often necessary to scarify and reshape gravel roads, in which case the road surface is scarified to at least the depth of the deepest holes, thoroughly harrowed with a heavy peg-tooth harrow, and shaped to cross section by a blade grader. The grader blade should be set at almost an angle of 90° to the road to remove waves or depressions. All loose stone should be removed and the grader used daily until the surface is well compacted. Fine gravel is added to fill all depressions.

209. Water-bound macadam.—*a.* The usual defects occurring in water-bound macadam are rutting and raveling, the latter being a condition where the road material becomes loose and loses its binding qualities. A former method of repair under horse-drawn traffic was to fill such ruts and raveled places with broken stone well tamped into place, but better results are now derived from using a bituminous material to bind the stone.

b. A general remedy for raveled, pitted, and dusty condition of water-bound macadam is a surface treatment with bituminous material and a cover of fine broken stone or screening. Where water-bound macadam has become badly worn, it is customary to scarify the surface to a depth of 2½ inches, remove loose material, or consolidate of grade and cross section, and then apply a wearing coat of about 2½ inches of bituminous macadam by the penetration method. This penetration method consists of pouring or grouting the bituminous material into the upper course of the road material before the binding of the material has been completed.

210. Bituminous pavements.—*a.* Defects usually occurring in bituminous pavements are raveling, bare, toothy, or pitted appearance,

and breaking down at earth shoulders. Raveling is caused by the failure of the binding material to perform its function, while bare, toothy, pitted appearances are due to lack of enough binder to flush to an even surface.

b. Repair consists in cleaning surface of all loose material, and filling, in case of ravel or depression, with a mixture of bitumen and broken stone of 1½-inch size, using a grade of asphaltic residuum oil or refined-tar product which can be applied cold or which requires very little heating.

c. Where bare and toothy places occur, the surface of the road is usually treated with a bituminous material, called road oil, applied to the cleaned surface at about ½ gallon per square yard and covered at once with ½-inch crushed stone, fine stone screenings, or coarse sand in sufficient quantity to bond completely with bituminous material and prevent stickiness.

d. Where the road breaks down at the sides, repairs should be made by cleaning out and filling with rock and road oil properly mixed, and building up the shoulders carefully with new material well compacted.

211. Concrete roads.—*a.* Defects in concrete pavements usually occur as transverse or longitudinal cracks, breaking up of paving at expansion joints, and disintegration at various places, owing to poor construction, improper foundation, and other causes.

b. In general, concrete roads can be kept in good repair if the earth shoulders protecting the edges of concrete are kept well filled and compacted, and cracks, as they appear, are well filled with bituminous binder or hot paving pitch. This should be done when weather conditions are such that cracks are widest, and care should be taken that sufficient bituminous material is used so that it comes to the surface of the roadway. This forms a waterproof joint and lessens the possibility of the disintegration of the concrete on either side.

c. Where disintegration occurs, the concrete in the area affected should be entirely removed, care being taken that the edges of openings are made true and square, and repair made by the application of new concrete brought to even surface with the surrounding roadway. The new concrete should be not less than 6 inches thick.

d. Where surface has become so badly worn or disintegrated that it may be necessary to resurface the entire roadway with bituminous concrete, or sheet asphalt to a depth of from 2 to 2½ inches, such a mat covering should be of a uniform thickness for the full width of the roadway. In this case, if not provided, it may be necessary to construct curbs in order to confine road covering.

212. New road construction.—In general, the utilities officer will be concerned mostly with repairs to existing roads, hence this manual does not cover details of new road construction. If the utilities officer has an extensive piece of new road to construct, he should consult one of the many excellent engineering books on road construction, such as the American Civil Engineer's Handbook by Merriman-Wiggin, published by John Wiley and Sons. He should also obtain from The Quartermaster General plans and specifications for a similar job and use these as a guide in preparing plans and specifications for the proposed road construction.

CHAPTER 7

WATER SUPPLY

213. General.—The quality of water supplied for consumption is a vital factor in the maintenance of the health and efficiency of a body of troops. Both quality and quantity of water have their bearing upon all questions relating to hygiene and sanitation at any military establishment whether it is a permanent military post or a temporary camp.

214. Quality and quantity.—Quality and quantity are of special significance in the industrial departments of quartermaster activities such as laundries, power, and heating plants. Water under pressure is also a powerful agency for the protection of property against destruction or injury by fire. There are, therefore, at least three important reasons why quartermasters should be interested in water-

supply engineering—protection of health, industrial uses, and fire protection.

215. Water-supply system.—The water-supply system may be divided into two parts, the source of supply and the distributing system. The source of supply may be a municipal supply system, a natural body of water, a reservoir, wells, or springs. The distributing system includes all main and lateral pipes, the standpipes and distributing reservoirs, gates, meters, all services, connections, etc. Auxiliary features are the pumping stations, tanks, filters, and water-softening plants.

216. Sources of supply.—*a.* In the investigation of sources of water supply consideration should be given first to the factor of potability or quality, then to quantity available, and finally to the practicability of obtaining a supply from any given source at a reasonable cost.

b. There are certain factors and conditions which preclude the consideration of some of the available sources, irrespective of the possibilities of known processes of purification. For example, it is not practicable to purify water containing large quantities of acid mine wastes or water polluted excessively with manufacturing wastes or sewage. Some waters containing large quantities of sodium chloride (salt) or other mineral matter in solution are not suitable for human consumption, and it is not practicable to convert them into potable supplies by any method of treatment other than distillation, which process is too expensive for the treatment of large quantities of water.

217. Chemically pure water.—Chemically pure water which is composed of hydrogen and oxygen is never found in a natural state. Rain water and snow, which are the ultimate sources of all water supplies, are not pure. As the raindrops and snowflakes pass through the atmosphere they come in contact with dust particles and other impurities which are in suspension in the air, and these materials becoming dissolved or entrapped by the raindrops or snow prevent water from this source from being chemically pure, and in numerous instances such water actually contains many bacteria.

218. Pollution.—In addition to the foregoing impurities, the atmosphere is polluted in varying degrees with gases of combustion and of decomposition. The amount of bacteria in the air ordinarily varies approximately in proportion to the amount of dust. It is found that many of the bacteria are attached to dust particles. Because of these conditions the number of bacteria in the air is greatest in or near large cities. The number diminishes as the altitude increases

and as the density of population decreases. The bacteria come chiefly from the soil and are carried into the air by winds and traffic movements. Bacteriological analyses show that most of the bacteria in the air belong to the harmless varieties. The bacteria which are dangerous to health come directly or indirectly from man and other warm-blooded animals (cattle, sheep, horses, etc.).

219. Bacteria.—*a.* Where reference is made to organic matter in dealing with the question of quality of water, the organic matter referred to includes not only dead organic matter resulting from the decay of plant life but also bacteria. Bacteria are very low forms of plant life.

b. Bacteria may be divided into two general classes—those which are injurious to the health of the human being, called "pathogenic" germs; and the other class, called nonpathogenic or "soil" bacteria, usually referred to as "saprophytic." Nonpathogenic bacteria are those that, although living as parasites, do not produce disease in bodies in which they live. Those responsible for proper water supply are chiefly concerned in devising means for the elimination of the first class, the pathogenic germs.

c. The amount of bacteria found in soil and in ground water decreases rapidly with the depth below the surface. It is generally found that very few bacteria exist below a depth of about 6 feet. In porous soils the depth is somewhat greater than in the dense clay soils.

d. Shallow wells and streams are therefore much more subject to pollution than deep wells, because the chief source of supply is the water which percolates over or through the surface soil in the immediate vicinity of the well or stream.

220. Bacillus coli.—*Bacillus coli* is one of the normal types of bacteria of the intestinal tracts of man and other warm-blooded animals. Its presence is usually the result of human or animal pollution. It is a harmless germ in itself but usually indicates the possible presence of harmful bacteria. *Bacillus coli* is usually expressed as "*B. coli*" and is an important term and widely used in the determination of pollution of water supply.

221. Determining qualities.—For determining the qualities of a water supply there are four classes of tests or analyses: physical, chemical, bacteriological, and microscopical.

a. Physical properties.—The physical properties are those which appeal to the sense of smell, taste, and sight. Among these are color, turbidity, and odor. These do not necessarily have any direct bearing upon the quality of water from the sanitary standpoint. It has been said that "a water may be safe but unsavory."

b. Chemical and bacteriological tests.—The chemical and bacteriological tests are of direct importance in determining the potability of any water supply. Both methods of examination should be made and the results properly correlated because it is unsafe to depend upon either one alone.

c. Microscopical examination.—The microscopical examination is of value chiefly in the study of a water supply with a view to its improvement by filtration, disinfection, etc. By means of the microscope it is usually possible to ascertain the cause of any odors or tastes which the water may temporarily possess.

222. Ground and surface water.—*a. General.*—Precipitation in the form of rain water as it comes in contact with the earth, runs off on the surface, or percolates through the soil is absorbed by plants or is again returned to the atmosphere by means of evaporation. Only those portions which remain on the surface or are stored in the soil become available as sources of water supply. We therefore have two great sources of supply, ground water and surface water.

(1) Ground water is rain water which has percolated into the soil.

(2) Surface water is rain water which has not percolated into the soil but runs off on the surface, or ground water which has come to the surface through springs.

b. Quality.—The water from these two sources varies greatly in quality. Ground waters generally contain more mineral matter in solution and less organic matter than surface waters. Because of this condition, surface supplies unless excessively polluted with sewage or other organic wastes are better for power and heating plants, post laundries, etc.

223. Chemical action; hardness.—*a.* The quality of both surface water and ground water is greatly affected by geological formations. Pure water is a powerful solvent. Rain water, being more nearly pure water and containing carbon dioxide as its chief foreign matter in solution, acts chemically upon some of the mineral substances contained in the rocks and soils through which it percolates or over which it flows.

b. The carbon dioxide being acid in character combines with calcium and magnesium elements which are constituents of some soils and rocks, forming the bircarbonates of these elements. This accounts for the temporary hardness of water. This action is much more intensive in the case of water percolating through great depths of soil or rock than it is on the surface of the earth. For this reason, ground waters in limestone formations have a high mineral content. Rivers and smaller streams in regions where the rock formation is

largely limestone contain relatively hard water because a considerable portion of the flow comes from ground-water sources.

224. Porosity of soil.—The extent to which streams are fed from springs and underground flow depends upon the porosity of the soil. This is well exemplified by the variable quality of water which is characteristic of some of the streams of this country. Numerous tests indicate that the mineral matter in solution in these streams changes in quantity with changes in rates of rainfall and temperature; the higher the rate of rainfall the greater the amount of water reaching a stream by surface flow or run-off. If the ground is frozen, percolation of rain water or snow water through the surface soil is cut off. Under this condition the water is free from mineral matter in solution, but the mineral matter in suspension often is greatly increased. The result is a soft but turbid water.

225. Characteristics of ground water.—Ground waters are more constant in their chemical characteristics than surface waters. They are also usually free from turbidity. On account of these conditions, ground waters usually are more easily prepared for sanitary and industrial purposes than surface waters, the chief objectionable factors being undesirable elements in solution such as sulphates, carbonates, magnesium, sulphur, iron, and manganese.

226. Use of ground waters.—The ground waters because of limited available quantities are rarely used for large municipal supplies. Wells, springs, and infiltration galleries constitute the ground water sources. With the exception of springs and wells which are located in districts of limestone formation, those sources are dependable for safe supplies unless polluted locally.

227. Supplies from lakes, rivers, or reservoirs.—*a.* Large municipal supplies and supplies for many military posts are almost wholly derived from surface-water sources, impounding reservoirs, lakes, or rivers. The impounded supplies are of better and more uniform quality than supplies taken from lakes and rivers. The latter are more subject to pollution and the water is more turbid and may, in the fall, have objectionable odors due to decaying leaves and other vegetation. On the other hand, impounded supplies are also subject to algae growths which cause tastes and odors.

b. With the rapidly increasing demand for larger municipal supplies resulting from the growth in population and tendency to greater per capita use, rivers and lakes must of necessity be more extensively used for sources of supply in the future. The rapid increase in density of population, which is now taking place within the drainage areas tributary to these sources, is an added menace to the purity of the

water supplies. With increased population on the drainage areas, the streams and lakes become more polluted. This in turn necessitates improvements in methods of purification.

228. Essential properties of water.—Although the presence of inorganic matter in water may be of sanitary significance, the organic matter usually is of great importance. Bacteriological tests and chemical analyses for the determination of organic matter, chlorine, and iron constitute the customary practice in the laboratory investigation of the quality of water for sanitary purposes. The quartermaster, however, is interested in other very essential properties of water in addition to those named, because he must not only provide a potable supply but also water suitable for culinary and laundry purposes, noncorrosive, and reasonably free from scale-forming elements. Water for sanitary purposes should be clear, odorless, tasteless, free from pathogenic or harmful bacteria, low in carbonates, sulphates, carbon dioxide, magnesium, iron, sulphur, manganese, and chlorides. These are the ideal characteristics. Water supplies possessing all of these desirable factors are rarely found.

229. Improvement of quality.—The improvement in the physical and chemical properties of water by means of special methods of treatment is a highly specialized subject in sanitary engineering. However, quartermasters should have at least a general understanding of engineering practice relative to such problems. The most important processes are sedimentation, softening, filtration, disinfection, decolorization, and deferrization as briefly described in chapter 8.

230. Water for steam boilers.—It is of utmost importance that steam boilers be supplied with proper quality of water. Hard water or water containing other objectionable incrusting matter causes corrosion, scale, foaming, overheating, and leaks, resulting in loss of heat, increased labor of attendance, increased cost of operation and repairs, a shortened life of boiler, and increased danger of explosion. All natural waters are more or less corrosive.

231. Planning supply; estimating consumption.—*a.* In planning a water-supply system for a permanent military establishment, it is necessary to make an estimate of the average daily consumption required for all purposes and add a sufficient amount to this quantity to provide for future liberally estimated additional requirements covering a period of 20 to 30 years.

b. It is much less difficult to estimate future requirements for a city than it is for a military post. As a rule it is possible not only to determine the rate of growth of a city but also to forecast its increase

in population for a period of 30 years with a reasonable degree of accuracy.

c. In the case of a military post this is obviously impossible. Such an establishment may have its population increased 100 percent or more in 1 or 2 years. This is one of the most difficult problems encountered in the planning of water-supply systems for military posts and for camps or other emergency military projects.

232. Distributing system, general.—*a.* The source of a proposed water-supply system and the quantity of water to be supplied daily having been determined, it is then necessary to plan the distributing system, the storage reservoirs, pumping stations, and filtration plant if required. One of the most important matters in connection with this work is the determination of proper limits of pressure for the water in the system, taking into account maximum requirements or rates of supply for both sanitary and fire-protection purposes.

b. The amount of storage suitable to meet the requirements of a water-supply system is variable. It depends upon many factors—source of supply, evaporation losses, leakage, capacity of pumping equipment, maximum rate of supply, whether water is filtered, whether sedimentation is necessary, distribution of rainfall, and fire protection.

233. Storage in impounding reservoirs.—The storage in an impounding reservoir, even where the total yearly run-off is not greatly in excess of the annual consumption, must be very large in order to conserve the supply during high rates of run-off, so that during dry periods of the year water may be drawn from storage to supply the deficiency between daily draft and daily inflow. Furthermore, there are wide fluctuations in amount of annual rainfall. Impounding reservoirs must be planned to provide storage which will be adequate for the driest years or periods of years. The effect of storage upon quality of water is usually beneficial to the quality, but there are conditions under which water deteriorates in storage. Storage offers exceptional opportunities for the growth of algae which give rise to objectionable odors. At the bottom of large reservoirs, decomposition of organic matter may take place, producing foul gases. Each project usually presents a different problem which requires careful study of the local conditions for a satisfactory solution.

234. Pipe lines.—The pipe lines or conduits for conveying water from headworks or intakes to storage reservoirs or distributing pipe systems are constructed of several classes of materials. Gravity or

nonpressure lines are constructed of vitrified clay, wood, cast iron, steel, brick masonry, plain concrete, or reinforced concrete. Lines subjected to pressure are constructed of wood, cast iron, steel, or reinforced concrete. There are several factors usually which enter into the problem of selection of material for such use—the permanency of the system, cost of construction, cost of maintenance, availability of material, its transportation charges, the construction difficulties presented by peculiarities of earth formation, watercourses, and transportation facilities, and the pressures to be provided for. If the conduit is not under pressure, the form of construction used may be an open channel or canal excavated in the natural earth, unlined or lined with concrete, or a masonry conduit located partially or wholly in an excavated trench or tunnel.

235. Cast-iron pipe.—*a. Use.*—Cast-iron pipes because of their strength and great durability are almost universally used in American cities for water distribution.

b. Standards.—A standard form of bell and spigot and standard thicknesses of cast-iron pipe for different diameters and different pressures have been adopted by the American Water Works Association and are in general use. Eight classes are provided called A, B, C, D, E, F, G, and H, and are designed for maximum heads of 100, 200, 300, 400, 500, 600, 700, and 800 feet respectively.

236. Pressure and head.—*a. Hydrostatic head.*—At any point in a pipe line, the hydrostatic head is the vertical distance in feet from the point taken up to the level of the free surface of water in the supplying reservoir or elevated tank.

b. Hydrostatic pressure.—The hydrostatic pressure in pounds per inch on the walls of the pipe at any point is equal to the hydrostatic head in feet multiplied by 0.4335. Conversely, the hydrostatic pressure in pounds per square inch (as read on a pressure gage) at any point in a pipe line when no water is flowing, multiplied by 2.3068, will give the hydrostatic head in feet at that point.

237. Loss of head.—The hydrostatic pressure referred to above will enable one to determine the hydrostatic head, i. e., the available head when no water is flowing in the pipe. When water flows in the pipe, the pressure gage hand will drop more and more as the velocity of the flow of water in the pipe increases. At any time during flow, the pressure existing at a point in the pipe line, multiplied by 2.3068, will give the pressure head in feet at that point, which will always be less than the hydrostatic head. This difference between the hydrostatic head and the pressure head is called the "loss of head." Loss of head is due to various factors, such as friction between the walls of

the pipe and the water flowing therein, entrance losses, and losses on account of change in direction, etc. Various formulas to compute the loss of head are given in hydraulic engineering textbooks, but for the utilities officer sufficient accuracy can be obtained from a four-line diagram as shown in figure 2. This diagram has a vertical line for each of the following factors:

	Line
Discharge in cubic feet per second and gallons per minute	1st
Size of pipe, diameter in inches	2d
Loss of head per 1,000 feet	3d
Velocity of flow in feet per second	4th

When two of the factors are known, a straight line connecting them upon the diagram will intersect the other two lines and indicate the other two factors whose values are sought.

238. Standard fire stream.—*a.* It very often happens that the required sizes of pipes in the distribution system will be determined by the requirements of water for fire-fighting purposes rather than the requirements for domestic consumption, hence the utilities officer should know what is meant by a standard fire stream.

b. A standard fire stream delivers 250 gallons per minute through a 2½-inch hose at the following hydrant pressures:

Feet of 2½-inch hose—	0	50	100	200	300	400	500	600
Required hydrant pressure in pounds per square inch—	45	56	63	77	92	106	121	135

c. In each case, the nozzle pressure will be 45 pounds per square inch after the water has passed through the connecting hose.

239. Distribution systems at posts and stations.—*a. Pressures.*—The water pressure maintained in military post systems usually ranges from 40 to 65 pounds per square inch. It is desirable that the pressures in a military post system be maintained within as narrow a range of fluctuations as practicable to avoid excessive charges for maintenance of system and plumbing fixtures. For extra pressure in time of fire, reliance should be placed on fire engines.

b. Consumption.—(1) *Domestic.*—The average domestic consumption at permanent posts and stations is generally between 150 and 200 gallons per day. However, during the shower bath periods (6 to 7 o'clock in the morning and between 4 and 5 o'clock in the evening), the peak rate of consumption will be nearly three times the average rate of consumption. As the system increases in age, the rate of consumption will increase owing to additional leaks developing in the system.

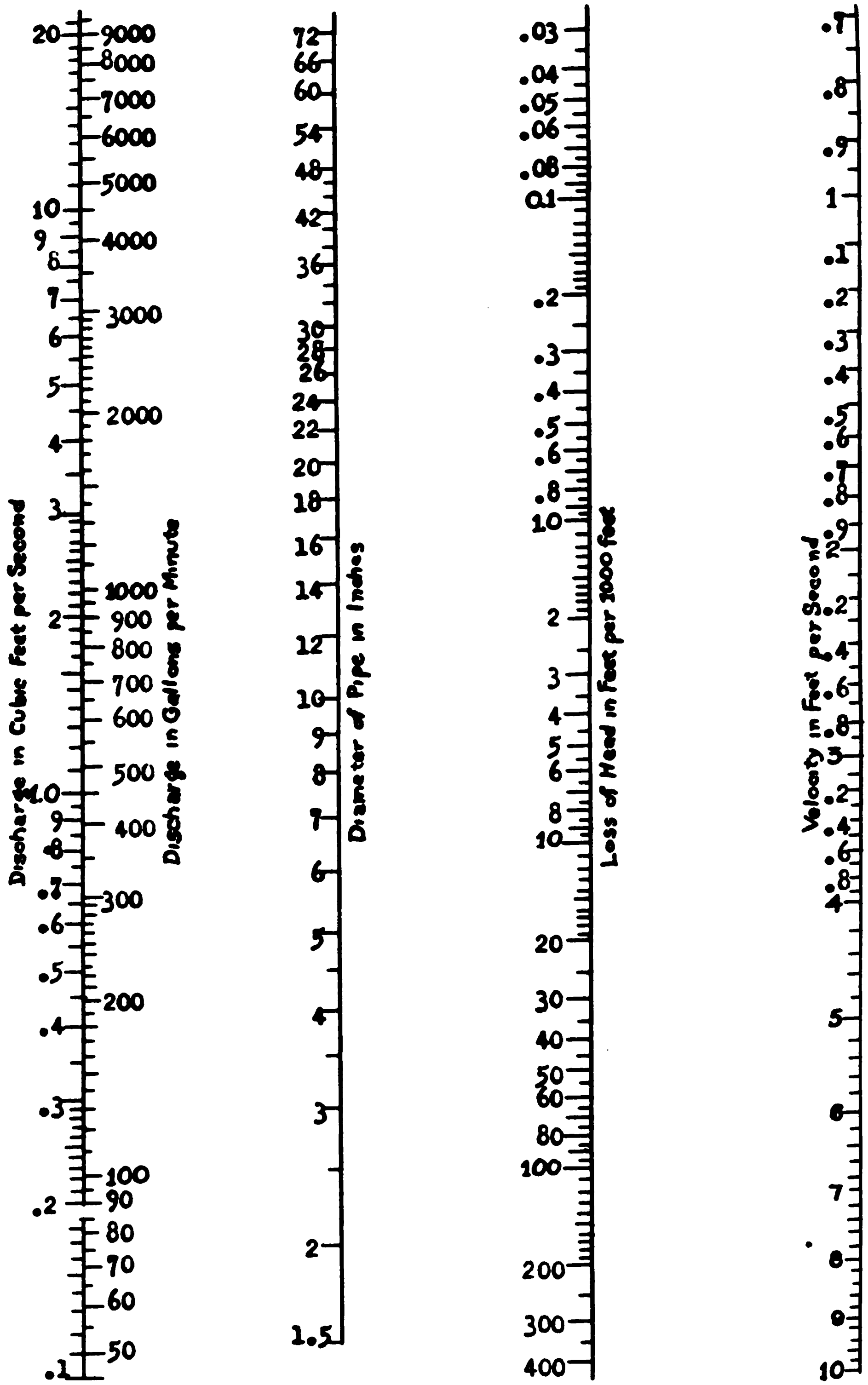

FIGURE 2.—Diagram for calculating cast-iron pipes.

(2) *Fire-fighting purposes.*—The requirements for fire-fighting purposes must be determined by the utilities officer after he has examined local conditions at the post in question. In one part of the post, for example, it may appear that no fire will occur which cannot be controlled by one standard fire stream, while in another part of the post it may be necessary to provide for two or three fire streams to overcome a fire in one of the larger buildings or in a group of buildings.

240. Distribution systems at camps and cantonments.—*a. Pressures.*—Inasmuch as camps and cantonments consist generally of structures not over one story high, a water pressure of 35 to 45 pounds at point of use will be satisfactory, dependence being placed upon the fire engines (pumpers) for the extra pressure required in case of fire.

b. Consumption.—(1) *Domestic.*—It has been found from experience that the per capita consumption will be in the neighborhood of 100 gallons per day, and provision for this quantity should be made. For animals, an allowance of 15 gallons per day per animal is ample. The peak loads occur as described in paragraph 239*b* above.

(2) *Fire-fighting purposes.*—Inasmuch as camps and cantonments are susceptible to serious fires because of their inflammable construction, provision should be made for sufficient pumpers to be available at all times to concentrate several fire streams upon a group of buildings. The number of fire streams that will be required can be estimated only after all local conditions are known, such as type of construction, distances between adjacent buildings, location and width of fire lanes, etc. The distribution system should be planned to provide by means of circuits, cross-connecting lines, sizes of pipes, etc., a sufficient supply of water for the number of fire streams estimated to be necessary for each area.

241. Pumping stations.—*a.* If the source of supply is at an elevation which is too low to permit of gravity flow from the headworks of the system to all parts of the distribution system at the required pressures, it becomes necessary to install a pumping station and elevated storage tanks.

b. Motor-driven centrifugal pumps are largely used for pumping water. Direct-connected motor drive is used whenever such units are obtainable. When such units are not obtainable, the belt drive is adopted. The latter units are less efficient and require more floor space in the plant.

c. As the rate of water consumption in any 24-hour period varies within a wide range at camps and cantonments, it is advantageous to provide several units for the regular service and sufficient number of reserve units to meet extraordinary demands and to meet such contingencies as pumps being out of commission for repairs, etc.

d. As a further safeguard against interruptions of service it is the customary practice to install an internal-combustion motor-driven pumping unit to be used at infrequent intervals when current is not available.

e. In many instances sufficient storage is provided so that pump or pumps will operate for long periods during the day at a constant rate, the peak demands for water being met by water from storage. This method is especially desirable in certain cases to prevent peak electric current demands.

242. Storage tanks.—Wooden tanks, generally ranging in capacity from 100,000 to 200,000 gallons, are very satisfactory for storage purposes for emergency water-supply systems. California redwood is the best material for use in the construction of these tanks. For permanent posts and stations, steel storage tanks are more satisfactory as they are less subject to leakage and do not deteriorate as rapidly. Reinforced concrete storage tanks, located on high ground elevations, are also frequently used and have low maintenance costs.

243. Medical Department regulations; sanitation.—The Medical Department is responsible for advising and making recommendations with reference to sanitary suitability of all water supplies for military personnel. No new projects for procurement of water supplies or extension of existing sources should be adopted until the Medical Department has been given opportunity to make recommendations as to suitability of the proposed source. In this connection the Office of The Quartermaster General works in cooperation with the Sanitary Section of The Surgeon General's Office.

CHAPTER 8

WATER PURIFICATION

244. Purification defined.—In the process of purification, it should be understood that the term "purification" as used in engineering literature should not be taken in the absolute sense, as none of the processes of treatment nor any combination of them will produce chemically pure water. "Purification" therefore simply means the restoration of any water which has been polluted or contaminated, or is objectionable because of certain chemical or physical properties, to a required degree of purity. A water may be satisfactory for domestic use yet unfit for industrial use, and vice versa.

245. Distinction; polluted and infected water.—A distinction should be made between a polluted and an infected or contaminated water.

a. Polluted water.—A polluted water is one that contains organic matter and the products of decay, either of vegetable or animal origin. A polluted water may not be injurious to health, although objectionable. Practically all surface supplies are polluted, and ground-water supplies show evidences of past pollution by the presence of chloride, albuminoid, ammonia, nitrates, and nitrites.

b. Infected water.—An infected water is one which contains specific parasites that cause disease.

246. Agencies of purification.—There are many agencies of water purification, some of which are natural and others artificial. The natural agencies are sedimentation, storage, filtration, disinfec-

tion, and decolorization by sunlight. The artificial agencies or processes are coagulation, sedimentation, filtration, areation, disinfection, and chemical treatment for the removal of objectionable salts in solution.

247. Expression of quantities.—The quantities of different salts in solution and the degree of color and turbidity are expressed in parts per million. The bacterial counts are given in numbers of colonies per cubic centimeter of water. Standard methods for analysis of water have been prepared by a committee of the American Public Health Association and are published in book form. The methods described in this manual are universally used in water analysis laboratories.

248. Turbidity.—The turbidity of water is that condition of opacity which is brought about by the presence of finely divided matter in suspension. The suspended matter may consist of clay, silt, finely divided organic matter, or microscopic organisms. Turbidity is measured in laboratories by comparing a sample of water in a standard-size glass tube with tubes containing samples of known values.

249. Color.—The color of water should not be confused with turbidity. The true color of water is caused by matter in solution. It is the color remaining after the suspended matter has been removed. The quantity of color is determined by comparing a sample of water with standard samples.

250. Odors.—Odors are designated according to the following standard terms:

a Aromatic	m Moldy
C Free chlorine	M Musty
d Disagreeable	p Peaty
e Earthy	s Sweetish
f Fishy	S Hydrogen sulphide
g Grassy	v Vegetable

The intensity of an odor is given by a numeral prefixed to the term expressing quality, for example, 1 C (very faint odor of chlorine), 3 f (distinct fishy odor), etc. Samples of water are tested for odor both when cold and when hot. Frequently there is a difference.

251. Chloride.—Chloride in water may result from mineral deposits, from ocean vapors carried inland by winds, or it may be the result of polluting matter such as sewage and industrial wastes. Sea water contains about 18,000 parts per million of sodium chloride (common salt). In water having less than 400 parts per million, the presence of this salt cannot be detected by the taste.

252. Sedimentation.—When a water supply is obtained from a river which carries a large amount of clay or loam in suspension, settling basins are usually provided to effect a partial clarification by allowing the water to stand until part of the suspended matter settles to the bottom. This settling of suspended matter is called sedimentation.

a. Methods of sedimentation.—There are two methods of clarification by sedimentation, plain sedimentation and sedimentation in conjunction with coagulation.

(1) *Plain sedimentation.*—Particles of sand and clay have a specific gravity of about 2.6; they are therefore held in suspension only by virtue of the currents maintained in the water. When these currents become retarded the suspended matter is gradually deposited, the rate of settling varying with the size and form of the particles. Very weak currents may be sufficient to hold fine particles in suspension, while the coarser material settles readily. To cause the deposition of the finer sediment it is therefore necessary for the water to be brought as nearly as possible to a state of rest.

(2) *Time required for sedimentation.*—The time required for satisfactory sedimentation is very different for different waters, and to determine this period actual experiments must be made. For some waters it requires weeks and even months to remove all the turbidity, while for others a settlement of a day or two accomplishes fairly good results. When the purpose of plain sedimentation is to prepare the water for further treatment, a high degree of clarification is not needed. The best period of sedimentation will thus depend upon the character of the raw water and the relation of the sedimentation to the operation of the entire plant.

(3) *Minimum time for sedimentation.*—For plain sedimentation a period of 24 hours' subsidence is about the minimum limit adopted, although in some cases a still shorter period may be sufficient. When more than 24 hours' subsidence would be required, then a coagulant should be added as described in *b* below.

(4) *Accumulation at bottom of reservoirs.*—It must be remembered that while subsidence removes bacteria from the water, it accumulates them in relatively larger quantities in the mud and ooze at the bottom of the reservoir. Not only do they accumulate there from deposition from superincumbent waters, but actual growth occurs in abundance in the rich organic matter of lake bottoms.

b. Sedimentation in conjunction with coagulation.—As applied to purification of water, coagulation is effected by adding to the impure water certain substances called coagulants which act chemically on

the impurities, forming precipitates which are more or less gelatinous in character. The application of coagulants causes the clumping together of the finely divided suspended matter into groups or aggregates having a rapid subsiding rate. The gelatinous matter causes bacteria and suspended matter to adhere to it, and being heavier than water tends to settle, dragging entrapped suspended matter with it. Color, to a large extent, is frequently removed by coagulation.

(1) *Use of coagulants.*—The use of coagulants in water purification was at first almost entirely confined to their employment in connection with rapid sand filters, but the great advantage of their use in connection with the subsidence of turbid waters makes them of value whatever the subsequent process may be.

(2) *Substances used as coagulants.*—Several substances can be used as coagulants. That most commonly employed is sulphate of alumina. When this substance is introduced into water containing carbonates and bicarbonates of lime and magnesia, it is decomposed, forming sulphates with the lime and magnesia, carbonic acid is set free, and the alumina forms a bulky gelatinous hydrate which constitutes the coagulating agent. If the water does not naturally contain a sufficient amount of alkalinity to decompose the necessary amount of coagulant, lime should be previously added to the water.

(3) *Quantity of coagulant used.*—With the ordinary quantities of coagulant used, such as 1 to 2 grains per gallon, the increase in hardness amounts to 9 to 18 parts per million, relatively not a very important matter and usually more than compensated for by the gain in clearness of the water. This objectionable increase in the permanent hardness may be avoided by the use of sodium carbonate (soda ash) instead of lime. The amount of chemical required depends upon the amount and character of the sediment, upon the degree of purification desired, and upon the permissible detention period. It varies in practice from about ¾ grain to 3 or 4 grains of sulphate per gallon, or 43 to 217 pounds per million gallons.

(4) *Rate of sedimentation.*—The rate of sedimentation depends greatly upon the amount of coagulant employed. Where the process is preliminary to rapid sand filtration, the period allowed is usually from 2 to 6 hours. In this case it is not desired that perfect clarification be secured, because better results will be obtained from the filters if a small amount of the flocculent coagulant is carried over to them; but too large an amount of sediment increases the cost of filtration more than the decrease in cost of sedimentation. Such matters as the amount of chemical needed, time of subsidence, and

degree of purification desired are intimately related, and the best and most economical arrangement must be worked out for each case separately.

(5) *Settling basins.*—Settling basins are constructed in accordance with the same general principles as those employed in the design of reservoirs; in fact in many cases reservoirs are used not only for storage purposes but also as settling basins. If there is much sediment, at least two basins are needed in order that one may be cleaned without interrupting the water supply. It is found also that generally better results can be obtained by the use of two or three basins in series than by the use of a single one of the same total capacity. While this effect can be secured by inexpensive partitions in a single basin, yet convenience in the removal of sediment makes it desirable to have at least two and often three independent basins. Where a coagulant is used after partial sedimentation, at least three would be necessary for convenient operation.

253. Filtration.—Filtration consists primarily in passing water through a porous substance that intercepts and retains the suspended matters contained in the water. In filtration as actually practiced, however, many other actions take place, which are sometimes even more important than the primary action of straining. There are two types of filters, the slow sand and the rapid sand or mechanical filters. Water which has passed through a sedimentation basin or through a coagulation and sedimentation basin is rarely in a satisfactory condition for use without further treatment. It is therefore necessary to free it of a large percent of the remaining finely divided suspended matter by means of filtration before it is discharged into a water-distributing system.

a. Slow sand filtration.—Slow sand filters consist of large, shallow, watertight tanks or reservoirs filled to a depth of 4 or 5 feet with special grades of gravel and sand. This filtering material is provided with underdrains which carry away the clarified water. The water passes downward through such a filter very slowly, usually at a rate not exceeding 5,000,000 gallons per acre per day. This process is effective in removing nearly all of the objectionable bacteria and other matter in suspension. It is a very satisfactory type of filter to use when conditions are suitable. The raw water must be low in turbidity. The efficiency of a slow sand filter is due not so much to the mechanical straining of the water through the sand as to a biological process that takes place in a jellylike film that is formed on the surface of the sand. This film, which is teeming with bacteria, is pervious to the water, but entangles and holds back

any solid substance that comes in contact with it, and if the matter so held back is of organic origin it is quickly destroyed by the micro-organisms in the jelly layer. When this jelly or sediment layer becomes so thick and dirty from the impurities it contains that sufficient water cannot pass through the filter, the water is drawn off and the bed cleaned by scraping off and washing a thin layer of the sand. The cost of construction of slow sand filters is high under most favorable natural conditions, but it is prohibitive in places where it is necessary to transport the filtering material a long distance.

b. Rapid sand filtration.—(1) In rapid sand or mechanical filters, the general process is the same as in slow sand filters except that a coagulant is generally used to form artificially a sediment layer on top of the filter bed to insure proper filtering action. Coagulants are added to the raw water by special apparatus. The essential and characteristic features of rapid sand or mechanical filtration are—

(*a*) Coagulation and sedimentation.

(*b*) Passing the water rapidly through a bed of sand and gravel.

(*c*) Facilities for cleansing the filtering sand by agitation and reversing the flow of water.

(2) As the rate of flow through the filter is high, averaging about 125,000,000 gallons per acre per day, the area of the filter is small in comparison with a slow sand filter, about 1/25 of the latter. The earlier designs were cylindrical in form and the tanks were constructed of wood or steel, but at the present time the practice is to use the rectangular form and construct them of concrete. Formerly revolving rakes were used for the agitation of the surface of the sand while washing the filter, but later compressed air introduced by a system of perforated pipes was extensively adopted for this purpose. The rapid sand method of filtratiton has been very extensively adopted in this country, largely because it affords a comparatively cheap means of rendering a very turbid water clear and attractive in appearance. When properly operated, these filters will remove 95 to 99 percent of the bacteria originally present in the water. The mechanical type of filter is in use at many of the military posts in this country.

254. Aeration.—The aeration process is extensively used to add oxygen to water for releasing gases held in solution. It is effected by passing water in thin sheets over weirs or inclined planes, by spraying it in the air from fountains or special nozzles, by allowing it to flow through perforated trays, or to trickle through coke or other

coarse-grained filters, etc. Removing gases requires more thorough agitation than the process of oxygen absorption. The gases most commonly removed by aeration are carbon dioxide, hydrogen sulphide, and other gases of decomposition.

255. Effect of sunlight.—Storage of water for long periods of time is beneficial in reducing turbidity, color, and bacterial content. Clarification is brought about as the result of long periods of sedimentation. The precipitation of both suspended organic and inorganic matter in a water, after it enters a large storage reservoir, is undoubtedly aided by the action of micro-organisms and the indirect action of sunlight in causing flocculation (gathering into flaky masses) of the organic matter. This floc has a coagulating effect which finally results in subsidence. Sunlight is also effective in bleaching water which is discolored by organic matter. It is most effective near the surface where the rays are rapidly absorbed in passing through the water. Sunlight has an effective penetration of only 5 to 10 feet in clear water. In this connection, spring and fall turnover of water is beneficial.

256. Copper sulphate treatment.—*a.* Copper sulphate is the chemical most commonly used in treating water for the elimination of algae. It is a poison and consequently should be skillfully introduced into the water in a reservoir so as to effect an equal distribution. When this is accomplished the water is safe for human consumption.

b. The amount of copper sulphate to be used should be accurately determined, based on the dosage necessary to kill the organisms and the volume of water to be treated. The usual maximum dosage does not exceed 0.5 parts per million (4.17 pounds per million gallons of water). In small storage tanks, algae may be eliminated by providing covers which exclude sunlight.

257. Disinfection; chlorination.—*a. General.*—Any substance which causes the destruction of pathogenic bacteria is a disinfectant. Chlorine either in the form of calcium hypochlorite (bleaching powder) or in the liquid form has been used for this purpose since about 1910. Chlorination is merely an adjunct to filtration, an added protection against an unhealthy water, and should always be considered only as such. The real purification must come from the filters, chlorination being a reinforcement in the bacterial reduction process. In chlorination, the chlorine combines with the hydrogen of the water, forming hydrochloric acid, which is precipitated, and the oxygen which is thereby liberated destroys the bacteria.

b. Liquid chlorine.—Liquid chlorine is used almost exclusively for disinfecting water in large quantities. It is less bulky than calcium hypochlorite (bleaching powder) and can be handled more easily in large plants. It is shipped in cylindrical containers holding from 100 to 2,000 pounds.

c. Introduction of chlorine.—The pressure in cylinders varies from 50 to 100 pounds per square inch. With suitable apparatus, liquid chlorine is easily introduced into the water in proper proportions for disinfection. The quantity to be used in any given case is determined by laboratory tests.

d. Bleaching powder.—Bleaching powder was extensively used by all armies in the field during the World War. It is put up in small tubes. The water is first filtered, if necessary, and then the bleaching powder is dissolved in a small amount of water and added to the filtered water. The amount of chlorine used is about 3.3 parts per million. The bleaching powder now obtained contains approximately 65 percent available chlorine and is purchased under Federal standard specifications. This material is quite stable and is much better for use than the product obtained during the World War.

258. Purification of water in the field.—A 36-gallon canvas bag, listed in the supply table as "bag, water, sterilizing," is issued by the Quartermaster Corps to organizations for use in the field. The purpose of this bag is to provide a stationary receptacle for the storage of water while being sterilized. It is suspended and filled, after which the water is sterilized by the addition of calcium hypochlorite, which is supplied by the Quartermaster Corps in measured doses in sealed glass tubes. Detailed instructions for the use of these hypochlorite tubes are set forth in Army Regulations and are not quoted in this manual because the purification of water by this method is not a function of the utilities officer.

259. Hard water.—Water which reguires a large amount of soap to form a lather, or which forms heavy incrustation on vessels in which it stands or is heated, is called hard water. The hardness of practically all water is caused by the following minerals which may be held in solution by it:

Calcium bicarbonate (limestone)	Temporary or carbonate hardness.
Magnesium bicarbonate (magnesite)	Do.
Calcium sulphate (gypsum)	Permanent or noncarbonate hardness.
Magnesium sulphate (epsom salts)	Do.

260. Water softening.—Hard water is unquestionably one of the most troublesome factors in utilities work with which a post quartermaster has to deal. It causes heavy incrustation in boilers, hot-water backs in kitchen ranges, and in all hot-water pipes. These incrustations cause rapid deterioration of the equipment and often are a source of considerable danger caused by the overheating of metal plates which are normally in contact with water. This has been the cause of many boiler explosions.

a. Removing causes of hardness.—Because hardness of water is caused chiefly by the presence of the soluble salts of calcium and magnesium, it is obvious that any process for removing hardness must involve the use of chemical reactive agents which will cause the precipitation of these elements.

b. Softening temporary hardness.—Substances producing temporary or carbonate hardness are held in solution by carbonic acid (carbon dioxide). The addition of lime removes the carbonic acid and precipitates the carbonates.

c. Softening permanent hardness.—Sulphates and chlorides which produce permanent or noncarbonate hardness are removed by the use of sodium carbonate (soda ash) or sodium hydrate. By this process it is practicable to reduce the total hardness to about 50 parts per million.

d. Zeolite process.—Zeolite is a hard, insoluble, granular mineral, a silicate of sodium. It possesses the remarkable property of removing all hardness from water by exchanging its sodium for the hardness-forming impurities in the raw water. Since these sodium salts are harmless and do not precipitate at ordinary boiler concentrations, the softened water is ideal for boiler feeding. The container for the zeolite is a steel cylindrical pressure tank similar in design to a pressure filter. The removal of the hardness of the water is effected by passing the water slowly through the granular mass of zeolite. It is a process of chemical substitution. The zeolite releases sodium and takes up the calcium and magnesium from the water. The sodium compounds do not cause hardness, so as a result the water is softened. After this action has progressed for a time, it is necessary to reverse the process so that the normal amount of sodium will be restored to the zeolite. This regeneration process is carried out by treating the zeolite with a 10 percent solution of sodium chloride (common salt). The sodium of the salt drives out calcium and magnesia and replaces them with a fresh supply of replaceable sodium. After regeneration, the salt solution is washed out and run off and the zeolite is ready again. In practice, it is

customary to design the plant so that it will contain a sufficient amount of zeolite to soften the water used in a laundry or power plant during the daytime and to restore it to its original condition by the regenerating process through the night. This process is very effective in removing both temporary and permanent hardness of water when the water is practically free from matter carried in suspension and has less than about 0.7 part per million of iron in solution. It is extensively used for softening water for laundry and boiler plant purposes, but is generally too expensive a process for water consumed for general domestic purposes at Army posts.

CHAPTER 9

PLUMBING AND DRAINAGE

261. Plumbing; general.—The comfort and healthful condition of living quarters depend in a great measure upon the adequacy and thoroughness of installation of the plumbing system; and as the health of a command is seriously affected by defective drainage it is necessary that the work of a plumber be thoroughly and conscientiously performed. It is therefore important that the utilities officer possess knowledge of the nature of materials used in plumbing and also be familiar with good plumbing practice in the installation of water supply and drainage systems.

262. Plumbing specifications.—Federal Standard Specifications No. WW-P-541 for plumbing fixtures for shore purposes must be used in connection with the procurement of plumbing and drainage work at Army posts. There is a long list of other Federal standard specifications for plumbing goods which will not be quoted in this manual but which can be found in the index of current United States Army and Federal specifications used by the War Department.

263. Elements of system.—*a. General.*—The essential elements of a modern plumbing system consist of—

(1) The cold-water distributing system for supplying water to all points within the building, the hot-water supply, and return circulation.

(2) Plumbing fixtures.

(3) The drainage, waste, or soil-pipe system.

b. Soil stack.—A soil stack is a vertical line of pipe connected to sewer or house drain and extending upward to the highest fixture in the building. The soil stack receives the discharge of the plumbing fixtures.

c. Waste pipe.—A waste pipe is a pipe directly connected to the fixture (except water closets) and extending to the floor where it is connected to soil pipe.

d. Vent stack—end vent or circuit system.—A vent stack is a vertical line of pipe on the upper end of the soil stack, extending up through the roof, thus ventilating the soil stack. This system of venting is known as the end vent or circuit system. It prevents siphonage and back pressure and requires no separate ventilating of traps. It is of interest to note in this system that if the clean-out plug is removed at the base of the soil stack a strong and continuous current of air will flow into the stack.

e. Clean-outs.—Clean-out plugs should be installed on all stacks and vent pipes at the lower end of flow or ground line.

f. Rain leaders.—Rain leaders, or conductors are pipes that conduct rain water from roofs to house drains, cisterns, or other places of discharge.

g. House drain.—The term "house drain" is applied to that part of the main horizontal drain, and its branches, inside the walls of the building, extending to and connecting with the house sewer.

h. House sewer.—The house sewer is that part of the main drain or sewer extending from the foundation wall of the building to its connection with the exterior sewerage system.

i. Roughing-in.—Roughing-in is the installation of the soil, waste, vent, and supply pipes from the points at which they enter a building to where the fixtures are to be set. In new buildings, this work is erected before the walls are lathed or the floors laid.

j. Finishing.—Finishing is the setting up of the plumbing fixtures and connecting them to the soil, waste, and supply pipes. This work is done after the plastering is finished and the floors are laid.

264. Water-distributing system.—The water-distributing system consists of all pipe lines that provide for distribution of water from service line to all fixtures within the building. The hot-water lines, including the return circulation, form part of the distributing system.

a. Service line.—The service pipe line is the line introducing water into the building. This forms the connection between the water main of the post or municipal distributing system and the water-distributing system within the building. In Government plumbing specifications, only that part of the service pipe line which is located within 5 feet of the exterior face of the foundation wall of the building is included in the plumbing work unless otherwise specified. The remaining portion of the service pipe line is included in the water-distributing system of the post.

b. Laying out distributing system.—(1) In laying out a water-

distributing system in a building, every effort should be made to simplify the work as much as possible. The lines should be direct and well-graded so as to provide for the complete drainage of the system when not in service.

(2) A stop valve should be installed in the main supply line (service line) at a convenient point just inside of the basement wall. The purpose of this valve is to make it possible to cut off the water supply of a building whenever occasion requires. Immediately inside the stop valve, there should be inserted a T-fitting and small pipe branch which should be provided with a valve, cock, or hose bib. This branch line provides a means of draining the system when the main stop valve is closed.

(3) The distributing pipe lines should be properly equipped with valves so that branch lines may be cut off for repair work without interrupting service in other parts of the system. For a similar reason, the supply to each fixture should be controlled by valves.

c. Piping.—All piping of the distributing system should be of galvanized genuine wrought iron, galvanized mild steel, or brass pipe. The pipe to be used depends upon the properties of the water. Brass pipe should be installed where the water becomes excessively corrosive when heated.

d. Hot-water distributing system.—In order to secure an efficient system for the distribution of hot water, the hot-water supply mains should be graded upward from the hot-water tank to the branch line of the most remote fixture. The hot-water mains and tanks should be covered with 85 percent magnesia or other effective covering material in order to prevent, as far as possible, loss of heat.

265. Hot-water storage tanks.—The hot-water storage tank of a plumbing system should be installed at a sufficient elevation above the heating surface of the water heater to insure good circulation. As a general rule, the bottom of a horizontal cylindrical tank should be above the heating surface of the fire box. In the case of vertical cylindrical tanks, it is not always possible to install them so that the bottom of the tank will be above the heating surface of the heater. This causes the water in the bottom of the tank usually to be cold and the tank, therefore, is only partially effective in storing hot water. When such a condition is evident, the tank should be hung horizontally at the ceiling or on a stand.

266. Steel and copper tanks.—Because some water supplies are very injurious to galvanized steel or iron by excessive corrosion when heated, it has been found necessary to install either copper silicon

alloy, or nickel clad steel tanks in the plumbing systems where water of such character is used. These metals are very much more resistant to corrosion than galvanized steel or wrought iron. Experience has shown in some instances that galvanized iron tanks can be maintained only for a period of 2 to 3 years. In such cases it has been the practice of The Quartermaster General's Office in recent years to substitute copper silicon alloy or nickel clad steel tanks for galvanized steel tanks having a capacity of 80 gallons or less.

267. Drainage system.—The drainage system consists of the house sewer or sewer connection, the main soil-pipe drain, the soil-pipe stacks, the branch waste pipes to fixtures, and the vent-pipe lines. The cast-iron soil-pipe house drain projects only 5 feet from the exterior face of the foundation wall and there connects with the vitrified pipe house sewer, which is regarded as a part of the exterior sewerage system. The dividing line between the plumbing system and the exterior system is arbitrarily drawn at a distance of 5 feet from the building. (See par. 264*a*).

a. Cast-iron soil pipe.—Extra heavy cast-iron pipe should be used for all underground soil lines in a building. The use of cast-iron soil pipe for these lines outside of the building is justified only when the lines are laid under a pavement or where roots of trees are apt to cause stoppages in vitrified-clay pipe lines. Whenever such conditions are found, it is advisable to replace the vitrified-clay pipes with cast-iron pipes.

b. Grade of sewer.—All interior cast-iron soil lines should have a positive grade toward the sewer of not less than $\frac{1}{8}$ inch per foot, preferably $\frac{1}{4}$ inch. Pipe should be laid in as direct and straight a line as possible.

c. Drain, soil, and waste pipes.—The stacks and vents and the ground soil lines are constructed of extra heavy cast-iron pipe, commercially known as soil pipe. Galvanized wrought iron or steel pipe with recessed drainage fittings is also used. No cast-iron pipe used should be less than 2 inches in diameter.

d. Traps.—(1) A trap is a device through which liquid and solid waste matter which the liquid may carry may freely pass, but which prevents the passage of air or gas in either direction. There are many forms of traps, the simplest being in the form of a downward loop in a vertical pipe. The loop is filled with water while the pipe on either side may be empty. Whenever water is run through a pipe, enough will be retained to fill the loop and prevent air or gas at atmospheric pressure from passing. If air has sufficient pressure, it may force the water from one side of the bend up the other until

air can escape past the bend and bubble upward through the water. The difference between the level of water when quiet and the point below top of the loop is called the seal of the trap.

(2) The requirements of a good trap are that it—

(*a*) Entirely and effectually prevents the passage of any air or gas from waste pipe backward into the house.

(*b*) Is constructed so that it can be readily cleaned.

(*c*) Cleans itself under all ordinary circumstances.

(3) Every fixture in a building should be trapped separately close to the fixture.

e. Siphonage.—The water which seals a trap is very likely to be drawn out by the suction of the water which passes down the waste line unless some means is used to destroy the suction. Suction is entirely prevented by the end vent or circuit system heretofore described.

f. Function of vent pipes.—The function of vent pipes is to eliminate variations in air pressure in a plumbing drainage system and thus avoid the creation of a nuisance by forcing or siphoning fixture traps and thus admitting foul air into rooms. All traps, of course, should be made safe against back pressure and self-siphonage under normal conditions of use. All vent outlets should discharge at least 2 feet above the highest part of roof ridge, coping, or light shaft, and as far away as possible from windows, light shafts, and water tanks.

g. Maintenance of water seal.—The maintenance of water seals between fixtures and drains, and airtight joints in waste pipes of plumbing systems, is obviously of much importance because it is by these means that the escape of foul air is prevented, and it is therefore important that the drainage system be tight and without danger of leakage.

h. Floor drains.—Interior floor drains or cesspools should not be installed unless a frequent flow of water is provided for trap seals. If floor drains are necessary in basements or other floors, a brass screw plug flush with floor should be provided.

i. Grease traps.—Grease is very troublesome because it is liquid and runs out of the sink readily when accompanied by hot water; but as soon as it encounters the cold surface of the waste or drain pipe, it solidifies and adheres to the pipe. The caliber of the pipe is thus reduced, and eventually it will be choked by the grease. A grease trap should be installed in the waste line from each kitchen or group of kitchens. The grease accumulates in a layer at water level, and if allowed to become cold will solidify into a cake which

can be easily removed. No sewage from lavatories or shower-bath buildings should be discharged into kitchen waste lines above the grease trap.

j. Rain-water drains.—According to the practice of The Quartermaster General's Office, all rain water is excluded from the plumbing system. A separate system of drains with independent outlets is provided for that purpose. This arrangement has certain important advantages which are as follows:

(1) It is possible to use smaller pipe lines in the collecting system of sewers.

(2) The amount of sewage to be treated and the maximum rate of flow of sewage at treatment plants are greatly reduced. The cost of plants therefore is much lower.

(3) There is less danger of flooding the basement floors with sewage.

268. Testing the plumbing system.—In the installation of new plumbing systems, all soil, water, and vent piping must be tested with water or air and must be proved tight before connection is made to sewer, trenches back filled, piping covered, or fixtures connected. All pipes must remain uncovered in every part until they have successfully passed the test.

a. Water test.—The water test is accomplished by closing all branches and filling the system with water and allowing the water to stand in the pipes for about 30 minutes to detect any leaks. Water piping that is to be concealed by structural work must be tested to a hydrostatic pressure of 100 pounds to the square inch and must be proved tight before pipes are concealed.

b. Air test.—When the weather is too cold for the water test, the compressed-air test is applied. In this case, the air is pumped into the system until a pressure of 10 pounds is indicated on the gage, when a valve between the pump and the system is closed. The presence of leaks is indicated on the gage by a decreasing pressure as the test continues. The leaks may be located by the forming of bubbles when a soap and water solution is applied to the joints with a brush.

269. Complex installations.—In complex plumbing installations where there are many fixtures, some of the controlling elements of the design depend upon the probable maximum number of fixtures which will be discharged simultaneously. Practical rules have been formulated which may be used as guides for such installations. Plumbing codes of cities and the War Department standard specifications for plumbing contain definite instructions in regard to most

of the essential dimensions and features of plumbing installations, methods of venting of fixtures, distance that certain fixtures may be placed from soil pipe stacks without providing back vents, etc.

270. Fixtures.—*a. Improvement.*—Plumbing practice and designs of fixtures have undergone very radical changes during the past few years. New types of fixtures have been added and many improvements in design of older types have been made. Some of the older types of fixtures were very wasteful. Much attention is now being given to improvements which will lessen water wastage. Manually controlled fixtures are being substituted for the continuous flow types and better flush valves adopted. The fixtures are more sanitary, wooden parts having been almost entirely eliminated, and integral porcelain or enameled iron fixtures have been substituted for the older designs made up of two or more kinds of materials.

b. Location.—(1) Fixtures should be located in a building so that the pipe necessary to supply them with water and carry off the discharges will not be run in exposed walls, although in many cases it may be safe to run pipes against the walls if they are exposed to the warmth of the room.

(2) Sinks and washtubs should be located as near windows as possible. Water closets, baths, etc., should be placed reasonably close to windows. Kitchen sinks should be placed convenient to the kitchen range, yet far enough away to be unaffected by heat radiated from the range or boiler.

(3) Fixtures on several floors should be arranged one over the other as much as possible and clustered in vertical rows so that only short branch waste pipes will be required to connect them to a soil pipe stack common to them all.

(4) Fixtures should not be set over living rooms, dining rooms, libraries, or other rooms where leaks are likely to cause great damage; rather, they should be located over kitchens, pantries, closets, etc. Soil and waste pipes should not be run in walls adjoining living rooms because the sounds of water falling down these pipes is disagreeable.

c. Lighting and ventilation.—(1) Any lavatory or latrine which is not provided with good ventilation and natural light is very faulty from the standpoint of sanitation. Natural lighting is much more satisfactory than artificial, and direct sunlight should be secured wherever possible. Fixtures and floors will be maintained in a more cleanly condition if the room is well lighted by direct or well diffused sunlight. In this respect the standard type of lavatory building used at camps and cantonments during the World War

is decidedly better than the majority of the permanent installations at military posts and stations. That type was developed in April 1917 and was used in all emergency construction projects in this country during that war.

(2) It is also important that a lavatory is well lighted from the standpoint of maintenance. It is then possible to detect leaks in fixtures and water wastage by partially closed faucets, etc. It is generally possible to trace a large percentage of the excessive consumption of water to these sources.

d. Water wastage; constant flow fixtures.—The continuous flow fixtures are the most wasteful in water consumption. These are being replaced with manually controlled fixtures.

e. Flush tank valve.—Another fixture which is responsible for a large amount of water wastage is the water-closet flush tank valve. The hollow rubber ball plunger becomes so distorted in form after a few months of use that it does not seat perfectly. The leakage resulting from this cause is constant and not readily perceptible, but the aggregate amount per day is large at most posts. It can be detected quickly by placing a small wad of paper against the water-closet bowl at a point just under the outlet of the flush pipe. If the paper is moistened it is evident that leaking is taking place.

f. Faucets.—Round-headed, self-closing faucets should be installed to prevent wastage.

g. Inspection.—Lavatory fixtures should be inspected frequently. In order to keep down water wastage, post quartermasters and utilities officers should exercise constant vigilance in this matter, make frequent inspection, and have repairs made promptly.

h. Water waste surveys.—Systematic surveys should be made from time to time to locate leaks in faucets, flush valves, and other fixtures and installations.

CHAPTER 10

SEWERAGE SYSTEMS

271. Sewerage.—Sewerage is a term which is applied to any system or works used in the collection and disposal of domestic and industrial liquid wastes and storm water in municipalities. Such a system may consist of a collecting system of sewers, pumping stations, treatment works, and outfall.

272. Definitions.—The following definitions for the various terms used in sewerage and sewage disposal practice are commonly used:

a. Sewage.—(1) Sewage is a combination of the liquid wastes, with such ground, surface, and storm water as may be present, conducted away from residences, business buildings, institutions, and industrial establishments.

(2) Domestic sewage is that taken from residences, business buildings, or institutions.

(3) Industrial wastes are the liquid wastes resulting from the processes employed in industrial establishments.

b. Drainage.—(1) Surface water is that portion of the precipitation which runs off over the surface of the ground.

(2) Storm water is that portion of the precipitation which runs off over the surface of the ground during a storm and for a short

period following a storm, in which the flow exceeds the noımal or ordinary run-off.

(3) Ground water is that which is standing in or passing through the ground.

c. Sewers.—(1) A sewer is a conduit for carrying off sewage.

(2) A common sewer is a sewer in which all abutters have equal rights of entrance and use.

(3) A house connection or house sewer is a pipe leading from a building to a common sewer.

(4) A lateral sewer is a sewer which does not receive the sewage from any other common sewer.

(5) A submain or branch sewer is one into which the sewage from two or more lateral sewers is discharged. These are also called district sewers.

(6) A main or trunk sewer is one into which the sewage from two or more submain sewers is discharged.

(7) An outfall sewer is one extending from the lower end of the collecting system to the point of final discharge into a body of water or into a sewage treatment plant.

(8) A separate sewer is one intended to receive domestic sewage and industrial wastes without the addition of surface or storm water.

(9) A combined sewer is one intended to receive domestic sewage, industrial wastes, and surface and storm water.

(10) An intercepting sewer is one generally laid transversely to the general sewer system to intercept all the sewage collected by the sewers of a separate system, or the dry weather flow of sewage and such additional surface and storm water as may be collected from a combined system. Intercepting sewers are sometimes built parallel to a stream for the purpose of collecting the sewage from a number of districts or outfall sewers and conveying it to a more advantageous point of disposal or to a treatment plant. These sewers are generally constructed with the primary object of eliminating a nuisance along a waterfront or protecting a water supply. Intercepting sewers are rarely designed with sufficient capacity to carry all of the storm water flow. They are, therefore, usually provided with overflows, so that the excess of storm water may discharge directly into a river at various points.

(11) A relief sewer is one designed to carry a portion of the flow from a district provided with sewers of insufficient capacity, and thus prevent overtaxing of the latter.

(12) A storm-water overflow sewer is one designed to carry the

excess combined sewage from a main or intercepting sewer to an independent outlet.

d. Drains.—(1) A drain is a conduit for carrying off storm water, surface water, and subsoil or ground water.

(2) A storm drain is a conduit for carrying off surface and storm water.

(3) A land drain is a conduit for carrying off subsoil or ground water, and for draining land.

e. Sewer system.—(1) A sewer system is the collecting system of sewers and appurtenances, together with such small pumping stations as may be required to lift the sewage from low-level districts.

(2) A combined system is one of combined sewers.

(3) A separate system is one of separate sewers.

f. Sewerage works.—Sewerage works comprise the sewer system, main pumping stations, treatment works, means of disposal of effluent and sludge, and all other works necessary to the complete collection, treatment, and disposal of the sewage.

g. Sewer appurtenances.—(1) A manhole is a shaft or chamber leading from the surface of the ground to the sewer, large enough to enable a man to gain access to the latter.

(2) A lamp hole is a small vertical pipe or shaft leading from the surface of the ground to the sewer, for admitting a lantern or reflected light for purposes of inspection.

(3) A wellhole or drop manhole is a vertical shaft in which sewage is allowed to fall from one sewer to another at a lower level.

(4) An inlet is a connection between the surface of the ground and a combined sewer or drain for the admission of surface or storm water.

(5) A catch basin is a chamber inserted in an inlet to prevent the admission of grit and other coarse material into the sewer or drain.

(6) A flush tank is a tank in which water or sewage is accumulated to be quickly discharged later, for the purpose of flushing the sewer.

(7) A regulator is a device for controlling the quantity of sewage admitted to an intercepting sewer.

(8) An outlet is the end of a sewer or drain from which its contents are finally discharged.

(9) A storm overflow is a weir, orifice, or other device for permitting the discharge from a combined sewer of that portion of flow due to excess of storm water.

273. Dry earth method of disposal.—The dry earth method of

disposal of human organic wastes has been used throughout the ages and still is the most practicable scheme for temporary camps. It is assumed that the reader is so familiar with this method of collection and disposal of wastes that it is unnecessary to discuss more than a few details of the subject. Standard plans for this method of sewage removal have been prepared and can be procured from The Quartermaster General or from quartermaster procurement planning agencies.

a. Objects to be accomplished.—The chief objects to be accomplished in this method of disposal of domestic organic wastes are the avoidance, as far as possible, of unsightly and malodorous matter and the prevention of transmission of disease by flies. Where earth pits are used, they should be kept covered tightly to prevent the entrance of flies. The pits should be 6 feet or more in depth. If the soil caves easily, the sides of the pit should be sheathed with boards to prevent caving.

b. Watertight receptacles.—Where the soil is very dense or rocky, pits cannot be used advantageously. In such cases watertight receptacles or pails must be used. Collections should be made daily. Cleanliness in handling, protection of the material from flies, regular and frequent collection, occasional disinfection of the pails, and convenient burial soil are essential to successful use of this method.

274. Water carriage system.—In the latter part of the nineteenth century, the water carriage system of sewerage came into general use in municipalities in this country. Most of the camps and all of the cantonments built during the World War were provided with water carriage sewerage systems.

275. Combined and separate systems.—There are two methods which may be used in the collecting sewer systems of a city; viz, the combined system which receives both domestic sewage and storm water sewage; and the separate systems, one system for domestic sewage and one for storm water. Nearly all of the older and larger sewer systems use the former method. It is generally cheaper to construct, but in several particulars it is less advantageous than the separate systems. Where the sewage must be pumped or carried long distances in pipe lines or purified, it is more economical to use the separate systems. The choice between the two systems is largely an economic one.

276. Organic matter in sewage.—*a. Composition.*—In domestic sewage the wastes are largely organic in character, partly in suspension and partly in solution. Combined sewers carry a large percentage of organic matter, chiefly on account of street washings. The

organic matter in sewage is composed of many different organic compounds, the most important constituents being urea, albumin, fibrin, casein, starch, sugar, fats, soaps, and cellulose. The concentration of these substances, that is, the amount present in a given volume of sewage, depends upon the per capita volume of the sewage, and varies widely in different systems and at different times in each 24 hours.

b. Action of decomposition.—The organic matter in sewage, whether in the liquid or solid form, is very unstable. It is constantly undergoing transformation owing to the processes of decomposition. These changes are brought about by bacterial action coupled with the disintegrating effect of turbulency of flow. Action of decomposition is intensified by heat. This accounts for the greater amount of accompanying odor in summer than in winter. Sewage may be obnoxious to the senses because of its decomposing organic matter, but it is potentially dangerous to public health only when it contains pathogenic bacteria.

277. Sewer gas.—Previous to the discovery of bacteria and the development of bacteriology, which is the foundation of modern hygiene and sanitation, sewer gas was generally regarded as a great menace to health. It is no longer feared by sanitarians, although the influence of the original conception still pervades the antique plumbing regulations and practice in many places. It is, of course, desirable to prevent sewer air from mixing with the air we breathe, as all impure air is debilitating. Furthermore, the foul-odored gases of putrefaction are extremely objectionable and therefore a nuisance. These, it should be remembered, are not a direct agency for the transmission of disease.

278. Catch basins; sewer inlets.—The catch basins, through which the street washings pass before entering the sewers, are usually trapped so as to prevent the escape of sewer gas into the atmosphere. These are also provided with a large chamber or silt basin, to intercept the detritus carried in the storm water. The water standing in those basins also has a large amount of organic matter which undergoes decomposition. These basins are in reality small septic tanks. The water in them forms an excellent place for the breeding of mosquitoes. In the best engineering practice of today, catch basins are being omitted from sewerage systems because of the adverse factors referred to and because of the cost of their maintenance and operation. In their place, well-designed sewer inlets are used. They should be equipped with strong and effective gratings.

279. Requirements for capacity; separate system.—In sewerage design work, as in many other classes of engineering design,

first consideration is given to the requirements for capacity—the loading. In a water system it is the maximum rate of consumption of water, but in a sewer system the load factors are maximum rates of discharge from house sewers, street inlets, industrial wastes, and ground-water seepage. In estimating the requirements for capacity in the case of sewers forming a part of a separate system for domestic sewage, it is customary to use the per capita water consumption as a basis. The extent to which the sewage flow varies from the water consumption depends chiefly upon the use of water for street washing, for lawn and garden irrigation, and the seepage into sewers from ground water surrounding pipe lines. Because there are so many indeterminate factors it is not possible to estimate with a high degree of accuracy the capacity requirements of any given sewer.

280. Sewers for military installations.—*a.* The sewerage work in connection with military installations is very important, as conditions of flow, characteristics of sewage, maintenance, and operating conditions present problems differing quite radically from those encountered in ordinary municipal practice. The works must be effective in meeting all essential public-health requirements and must be so simple in details of construction that the work can be executed in the shortest possible time. It is obvious that a military post or cantonment cannot be used for the shelter of troops until the sewerage facilities are completed and in good working condition.

b. The sewerage systems for cantonments as well as for permanent military establishments are designed for the removal of domestic sewage only. Where a treatment plant is a necessary feature of a system, all surface drainage should be carefully excluded in order to avoid the construction of very large sewers and the expense of treating large volumes of sewage during storms.

c. In planning the sewer systems for the cantonments built during the World War, it was found that the maximum rate of discharge occurred during the shower-bath periods. This is a factor which is peculiar to military establishments. As a result, there is a much wider range of rates of flow in a 24-hour period than is found in most municipalities.

d. Tests made in several of the posts, camps, and stations showed that the maximum rate of flow from a divisional cantonment was approximately 2½ times the average rate for 24 hours, and this maximum flow continued for a period ranging from 40 to 60 minutes. The sewers therefore must be so designed as to have sufficient ca-

pacity for these maximum rates, otherwise overflowing would ensue and nuisances would be created. The per capita daily rate of sewage flow is assumed to be equal to the per capita daily rate of water consumption.

281. Preliminary surveys.—The preliminary surveys and maps used in the preparation of working drawings for a system of sewers should be carefully made. There is much more need for accuracy in this preliminary work than in the case of a water supply system, although both are largely hydraulic problems. The gradients and sizes of pipe lines in a collecting system of sewers require very careful adjustment in order to maintain suitable velocities of flow and prevent overtaxing the capacity of some of the sewers. In order to provide a "factor of safety" or sufficient capacity for unforeseen conditions of flow, it is customary practice to design a sewer on the assumption that it would be approximately two-thirds full during highest anticipated rates of flow.

282. Self-cleansing velocity.—In all problems dealing with the hydraulics of sewerage systems, excepting minimum velocities, sewage is regarded as equivalent to water, i. e., the same coefficients are used in the hydraulic formulas. The minimum allowable velocity to be adopted in any case is a very important factor. If the velocity is too low, some of the matter carried in suspension will settle to the bottom of the sewer, forming deposits which may cause a complete stoppage of flow. The minimum mean velocity at which sewerage will flow, without allowing deposits to form, is called the "self-cleansing" velocity. This velocity is different for different kinds and conditions of sewage. Velocities may be allowed as low as 1.5 to 2.5 feet per second for domestic sewage, with sewer half filled, but in combined systems it is good practice to allow generally a minimum of 3 feet per second. The lateral sewers and house connections require higher values for self-cleansing velocities than the trunk and outfall sewers in the same system.

283. Gradients and pumping.—In any given area where the variation in surface elevations is little, it is readily seen that the question as to minimum gradients is very important in order to obviate the necessity for pumping or to reduce the volume of sewage to be pumped.

284. Alinement of manholes.—It is general practice to construct sewers less than 3 feet in diameter, on a uniform gradient, and straight alinement between manholes. This facilitates inspection and cleaning. The manholes afford access for inspection and

cleaning purposes. They should generally be placed at intervals of not more than 300 feet. In large-size sewers and outfall sewers, the distance between inspection openings may be considerably greater. All changes in gradients and alinements should be made at manholes. In no case should the angle of deflection be greater than 90°.

285. Gradient table.—The following gradient table gives carrying capacities and approximate number of persons served by various sizes of vitrified clay sewer pipe, with a velocity of 2½ feet per second, flowing full. A sewer two-thirds full (par. 281) will discharge 0.8 as much as when it is flowing full. The velocity of flow in a sewer is the same when it is half full as when it is full. The maximum velocity occurs when it is nine-tenths full, being about 10 percent more than when it is half full or full. In special cases, in order to avoid very deep excavations or the pumping of sewage, a minimum velocity of 20 inches per second is allowable.

TABLE OF MINIMUM GRADIENTS

[Carrying capacity of various sizes of pipe when laid on minimum grades; velocity, 2.5 feet per second, flowing full]

Size (inches)	Minimum grade (percent)	Carrying capacity (cubic feet per second) [1]	Maximum number of men
6	1. 00	0. 49	1, 200
8	. 64	. 87	2, 085
10	. 45	1. 36	3, 285
12	. 34	1. 96	4, 580
15	. 24	3. 07	7, 200
18	. 19	4. 42	10, 320
21	. 15	6. 01	21, 600
24	. 12	7. 85	34, 560
27	. 10	9. 94	47, 520
30	. 09	12. 27	59, 760

[1] 7.48 gallons = 1 cubic foot.

286. Water carriage systems; sewage disposal.—It is apparent from a review of the history of the development of water carriage sewerage systems that during the early period little thought was given to the question of methods of sewage disposal. The liquid wastes were introduced into the sewers by plumbing fixtures, house drainage systems, and storm water inlets, and transported by the collecting system of sewers to the outlet of the outfall sewer and there discharged. These foul liquid wastes were usually discharged directly into a stream, a lake, the ocean, or other body of water. This method of disposal later became known as disposal by dilution,

a term which sounds well in discussions on sanitary engineering but in reality is usually pollution of natural bodies of water. It is obvious, therefore, that the introduction of water carriage sewerage systems has intensified greatly the pollution of bodies of water, rendering them in many cases not only unfit for sources of water supply but affecting seriously their usefulness for industrial and recreational purposes. Small streams which are used for this purpose eventually become so overloaded with decaying organic matter that they are a nuisance on account of foul odors and unsightly appearance. Thus they become open sewers—a continuation of the sewerage system. Such unfortunate conditions have developed as a result of the rapid increase in population in areas tributary to systems and also because of a lack of provision for adequate means of disposal.

287. Classification of sewage.—For the purposes of sanitary science, matter is divided into two general classes, organic and inorganic.

a. Organic matter.—(1) *Definition.*—Organic matter is the substance of which living bodies, whether animal or vegetable, are composed. It is very unstable and, after the organisms die, gradually changes to inorganic compounds through a process of chemical decomposition.

(2) *Sources.*—The organic matter in sewage is derived from various sources and not all is equally harmful. When discarded by animal life, and particularly human life, it is the most dangerous because it may contain germs of disease; and, although chemical analysis may show a marked degree of purification, an effluent from sewage which contains organic matter derived from this source is more dangerous than one in which the organic matter is derived from plant life, and particularly from vegetable matter that has been used as food.

b. Inorganic matter.—Inorganic matter is the name applied to all matter existing outside of living organisms or that is not necessarily a constituent of living beings. The simple substances which organic matter is composed of are found also in inorganic matter but differently combined.

c. Effects of organic and inorganic matter on sewage.—Both organic and inorganic matter are contained in sewage, but as a rule the inorganic matter is of little sanitary importance, since it possesses no disagreeable or dangerous properties and is chiefly objectionable on account of the volume it contributes to the amount of sludge or waste that must be removed from purifying tanks. The organic matter that

is objectionable in sewage seldom amounts to more than 1 part per 1,000 parts of sewage in cities with an adequate water supply. Yet it is this small amount of organic matter which, by reason of the putrefactive or rotting changes through which it passes and the lower forms of life that may be associated with it, gives sewage its disease-producing power as well as its offensive odors.

288. Progressive changes in sewage.—Sewage is an unstable product which is constantly passing through successive transformations tending toward the complete breaking up and oxidation of the organic matter. These natural changes are so rapid that samples of sewage taken at various points along an outfall sewer of considerable length show a distinct progression in some of these transformations. Many of the phenomena that occur in the process of purification are intricate and variable and not thoroughly understood, but some general principles have been formulated which must be understood in order to operate sewage purification plants properly.

289. Bacterial composition of sewage.—*a. General.*—Bacteria are microscopic organisms belonging to the vegetable kingdom. They are closely allied to the fungi, yeasts, and molds. According to their mode of living, bacteria are classified as aerobic and anaerobic. Aerobic bacteria live and multiply only in the presence of air or free oxygen. Anaerobic bacteria thrive only in the absence of oxygen.

b. Saprophytic and parasitic bacteria.—Bacteria are further divided into saprophytic and parasitic.

(1) Saprophytic or refuse-eating bacteria obtain their nutriment from dead organic matter; exist independently of a living body; and are generally harmless to living organisms. The saprophytic bacteria bring about the changes which reduce organic matter to harmless compounds; hence this class of bacteria is of the greatest aid and importance in the process of sewage purification.

(2) Parasitic bacteria live on or in some other organism from which they derive nourishment; they cannot thrive independently of a living body. They are of special importance in sewage purification because some varieties of them cause many diseases. Parasitic bacteria are divided into pathogenic and nonpathogenic. Pathogenic bacteria are those which produce disease in man or other animals. Nonpathogenic bacteria are those which, although living as parasites, do not produce disease in the bodies in which they live.

c. Sources of infection.—Pathogenic bacteria may be taken into the body system in food, drinking water, with the air breathed, or through abrasions in the skin. The sources of infection most important in studying the subject of sewage purification and disposal are food and

drink, as these sources are more liable to pollution from sewage than others.

d. Presence of bacteria.—(1) Bacteria are always naturally present wherever organic matter exists, and their number is nearly proportional to the amount of organic matter. The efficiency of water filtration plants is generally expressed in terms of the number of bacteria found before and after filtration. Bacteria are present in air, in soil, in water, and in all organic matter which may exist in any of these elements. Spring water and deep-well water may be free from bacteria, but ordinary surface water whether contaminated by sewage or not contains a great many of them.

(2) The number of bacteria present in any water is expressed as the number per cubic centimeter. The presence of more than 100 bacteria per cubic centimeter is considered to make the water unfit for use. As water becomes contaminated with organic matter, the number of bacteria increases in proportion to the amount of organic matter, becoming 3 or 4 million per cubic centimeter in badly polluted streams.

(3) Since the effect of the presence of saprophytic bacteria is to oxidize organic matter, which is the desired end of all sewage-purification processes, it follows that a large number of such bacteria present in sewage during its treatment is most desirable and beneficial. It also follows that any process which introduces chemicals or methods that attack these bacteria is fundamentally wrong in principle.

(4) The good effects of saprophytic bacteria must be appreciated fully and at the same time the bad effects of pathogenic bacteria must not be forgotten. These latter are not found except in water polluted by animal waste. The number of pathogenic bacteria is supposed to bear an approximately constant ratio to the total number of bacteria. The detection of pathogenic bacteria is still a difficult matter even with the present refinements of bacterial science.

290. Dissemination of infectious diseases.—*a. Infection from men and animals.*—Typhoid fever may be taken as a type of the epidemic infectious diseases. It has been found that every case of typhoid fever arises from an antecedent case. For a limited time, and under conditions particularly favorable, pathogenic bacteria may multiply outside the human body. It may be said, however, that for the most part man and other animals are the principal if not the only immediate sources of infection. These infectious maladies are attributed directly to infection from the bowel discharges. Bowel discharges readily mingle with and infect almost any substance in the environment. They are particularly dangerous when mingled

with the water of a stream. The disease germs contained in bowel discharges may be disseminated by air, dirt, dust, sewage, water, ice, milk, vegetables, insects, and other ways.

b. Polluted water supply.—(1) Water is one of the most common vehicles of disease, and by far the greatest number of infectious diseases are traced to an infected water supply. Formerly it was believed that the water of a flowing stream purifies itself and that the dilution of foul water to such an extent that chemical analysis could not detect sewage contamination rendered it innocuous. Later investigations, however, disproved these beliefs especially in regard to the destruction of pathogenic bacteria.

(2) Dilution, time, and sedimentation are the factors which contribute most to the purification of flowing streams. These factors, however, can not be depended upon, except to a very slight degree, to destroy the germs of infectious diseases with which water has been infected. This is shown by statistics of numerous cities which have taken their water supply from streams subject to pollution above the point of intake.

291. Sanitary terms.—In the study of a subject of this character, it is essential that the student become familiar with the meaning of the terms employed. The following definitions have met with general acceptance among sanitarians:

a. Sewage disposal is a generic term applied to the act of disposing sewage by any method.

b. Sewage treatment is the process to which sewage is subjected in order partially to remove its impurities or so change them as to render the effluent fit for final discharge into a stream, lake, or other body of water.

c. Contamination is the introduction into water of bacteria or other substances which render it unsafe for human consumption.

d. Pollution is the introduction into water of substances of such character and in such quantity that they render the river or other body of water objectionable in appearance or cause it to give off objectionable odors.

e. Influent is sewage or partially treated sewage flowing into any sewage treatment device.

f. Effluent is partially or completely treated sewage flowing out of any sewage treatment device.

g. Stability is the capability of sewage or effluent to resist putrefaction under the conditions to which it is subjected.

h. Settling or settleable solids are those suspended matters which will subside in quiescent sewage in 2 hours.

i. Clarification is a relative term denoting the partial removal of suspended and colloidal matter by straining, sedimentation, or by coagulation and sedimentation.

j. Colloidal matter is the suspended matter which is so finely divided that it will not subside in 2 hours.

k. Sewage oxidation is the process whereby, through the action of living organisms in the presence of the air, the organic matter is converted to a more stable condition or into mineral matter.

l. Sludge is the suspended solids of the sewage deposited in tanks or intercepted at the surface of filters, mixed with water.

m. Sludge digestion is the biological process by which organic matter in sludge is gasified, liquefied, mineralized, or converted into stable organic matter.

n. Scum is a mass of sewage solids buoyed up in part by gas or grease, and which, consequently, floats at the surface of the sewage.

292. Biological purification of sewage (reduction of organic matter).—The modern method of sewage purification, which may be called the biological method, rests on the principle that organic matter is mineralized by micro-organisms. All methods by which organic wastes are transformed into harmless products through natural agencies may be classed under this head.

293. Sewage-treatment processes.—*a. Nomenclature.*—Sewage or other organic liquid wastes may be disposed of by the natural process previously referred to or by one of several artificial processes. The latter methods, termed sewage-treatment processes, are—

(1) Intermittent sand filtration.
(2) Chemical precipitation and filtration.
(3) Tank treatment and filtration.
(4) Activated sludge process.

b. Types of plants.—Many types of plants and special devices have been used in the treatment of sewage. Some of these are now regarded as obsolete. Others have undergone modifications and have been improved, and efforts are being made constantly to perfect them.

c. Objects accomplished by treatment.—It is generally accepted that sewage treatment processes accomplish three things:

(1) Removal of a large percentage of suspended matter.
(2) Reduction of such suspended matter to a stable condition.
(3) Oxidation of the organic matter in solution.

d. War Department sewage treatment plants.—This type of plant accomplishes the three primary objects of sewage treatment with minimum funds for construction and the lowest unit cost for opera-

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tion. Simplicity in detail and the omission of nonessential features have made this possible. This type of plant has been approved by the Medical Corps of the Army.

e. Elements of War Department plant.—The elements of the typical War Department sewage treatment plant are the screen and detritus chamber, the sewage tanks, siphon chamber, trickling filter, chlorination chamber, secondary sedimentation tank, and sludge beds.

f. Screen and detritus or grit chamber.—The grit chamber is a chamber or enlarged channel in which the cross section is so designed that the velocity of flow is such that only heavy solids, such as grit and sand, are deposited, while the lighter organic solids are carried forward in suspension. Sloping bar screens are inserted in these channels. The screens are effective in separating floating matter such as bits of wood, paper, and other coarse matter. The sewage flows from the grit chamber into the septic tanks.

g. Sewage tanks.—The tanks consist of a multiple series, single story, sedimentation, and digestion chambers. Each chamber is built with vertical side walls and has an inverted pyramidal bottom Pipes are provided which permit the removal of sludge from bottom of chambers by hydrostatic pressure, this work being accomplished without emptying the tank. The baffle walls at inlet and outlet are inclined. The baffles at divisional walls are vertical. The salient features of the sewage tanks are—

(1) Inclined and vertical baffles, extending horizontally across tank, which cause an even distribution of flow throughout the cross section of the tank, reduce eddying and disturbance of scum and sludge to a minimum, and trap floating matter.

(2) Large space for the accumulation of sludge.

(3) Sludge removal easily accomplished without the unwatering of a tank.

(4) A high degree of clarification obtained on account of the weirs and baffles which divide each tank into several compartments.

h. Action in tanks.—(1) The organic solids as they enter a tank are deposited for the most part in the hopper-shaped bottom of the first compartment. This action is known as sedimentation. In a tank in which the biological processes are well established, the organic solids are disintegrated by the action of bacteria and microscopical organisms. The more finely divided the suspended organic matter is upon reaching the treatment plant the more rapid will be the digestive process in the tanks. The products of this tank action are gases, water, and a black, finely divided matter which is called

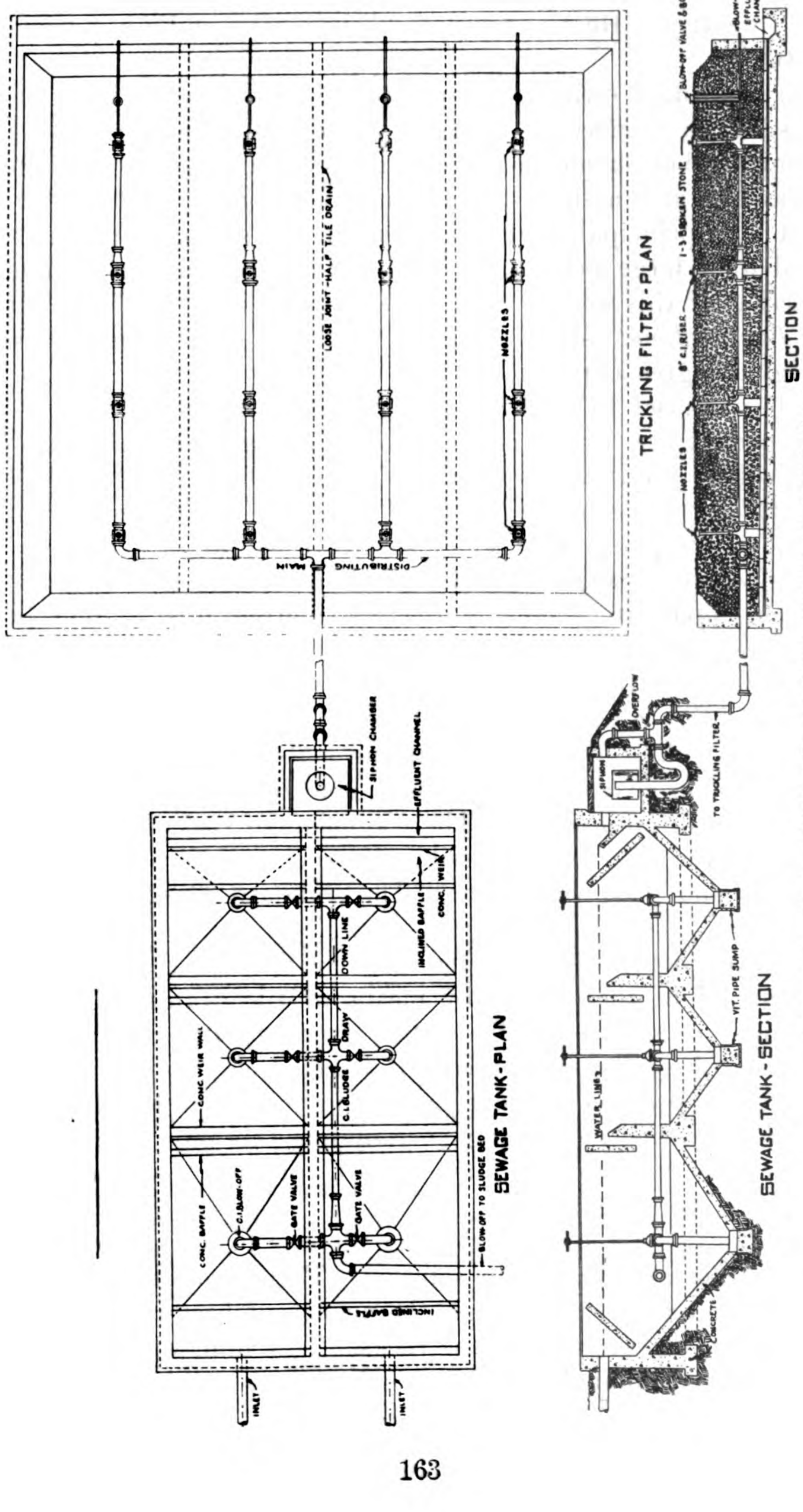


FIGURE 3.—Typical United States Army sewage treatment plant.

sludge. During warm weather this action is more vigorous than in cold weather. Heat stimulates chemical and bacteriological reactions.

(2) At times, owing to imperfect digestion, scum will form in tanks on the surface of sewage. Scum should not be allowed to accumulate but should be broken up by pole, hose, or other device. A heavy scum is a sign of inefficient operation.

(3) The principal accomplishment in the sewage tank is the removal of a large percentage of the matter in suspension and the reduction of this matter to a stable condition.

i. Tank effluent.—It is desirable that tank effluent be clarified to as high a degree as possible so that the subsequent treatment in filter will be required to oxidize organic matter in solution only. The more perfect the process of clarification in the tanks, the more complete will be the treatment in the trickling filter.

j. Siphon; intermittent flow of effluent.—The effluent from the sewage tanks passes over long, sharp-crested weirs and flows into the siphon or dosing tank. The function of the siphon is to produce an intermittent flow in the distributing pipe system in the rock filter. By this means the discharge of tank effluent is evenly distributed over the surface of the filter.

k. Trickling filter.—(1) This type of filter is known as a sprinkling or trickling filter. The filtering material is crushed rock of a hard, durable character which will not disintegrate as the result of chemical or frost action. The fragments of rock should be coarse and as uniform in size as possible in order to insure large voids in the mass and good ventilation. The standard depth of filter is 5 feet.

(2) Provision is made in the concrete floor of the filter for the carrying off of the effluent by means of tile drains. The gutters or drains are spaced equally distant from the lines of distributing mains and are covered by pieces of vitrified clay split pipes laid in an inverted position without mortar in joints on 1-inch supports. The broken stone immediately surrounding this pipe is coarser than that in other parts of the filter so as to provide less obstruction to the flow of the effluent.

(3) The purpose of the trickling filter is to oxidize organic colloidal matter and matter in solution. This is effected by destruction of organic matter through the agency of bacteria in the jelly-like film on the surfaces of the rocks. This film, which is teeming with bacteria, entangles and holds back any solid substance that

comes in contact with it, and if the matter is organic it is quickly destroyed by the micro-organisms in the jelly layer.

l. Distribution by spray nozzles.—(1) The tank effluent is distributed over the trickling filter by means of spray nozzles so designed as to convert the jet into a fine spray. The spraying period is between 1 and 2 minutes.

(2) Trickling filters have a capacity for treating two to four million gallons of tank effluent per acre per day (24 hours). The capacity of filters is also given in terms of population per acre. On this basis they have a capacity of from 20,000 to 30,000. The latter rate was used by the War Department during the World War.

m. Sludge bed.—(1) After sludge in sewage tanks is thoroughly digested, it is run off through pipes from the bottom of the chambers to the sludge bed.

(2) The sludge bed usually consists of a rectangular bed of about 10 inches of gravel covered with 3 to 4 inches of sand or an equivalent total depth of cinders. The bed is surrounded by an earth bank high enough to hold a 12-inch dose of sludge. The bed is provided with underdrains laid 8 to 10 feet apart. It requires about a week for reasonably well-digested sludge to dry to a spadable condition, at which time it has the appearance of black earth, has no appreciable odor, and can be used for filling purposes about the plant.

(3) The effluent is nonputrescible, free from pathogenic bacteria, and can be discharged into streams. It is often desirable to loosen up the surface of the bed with a harrow after the sludge has been removed.

(4) Sludge is said to be well-digested when upon being drawn from a tank it has little odor which is not disagreeable, and does not attract flies when exposed to the atmosphere in warm weather. It should dry to a forkable condition in average summer weather in 3 to 6 days.

n. Chlorination; secondary sedimentation.—In some plants where it is particularly necessary to secure a final effluent which is as free as possible from suspended matter (humus), a small secondary sedimentation tank is installed to receive the flow from the filter. If disinfection is required in order to render the final effluent from a plant safe for discharge into a body of water or a stream which is used as a source for water supply, the disinfectant should be introduced into the effluent as it enters the secondary sedimentation tank. It should be well mixed with the inflowing water. Liquid chlorine and hypochlorite of lime are the disinfecting agents most commonly used for this purpose.

o. Standard designs of War Department tanks.—(1) Standard designs of tanks suitable in capacity for populations ranging from about 100 to 5,000 are on file in The Quartermaster General's Office. These are designated as sizes A, B, C, and D. Special drawings are prepared for larger sizes. Many plants in which this type of tank was used were built at camps, cantonments, and other Military Establishments during the World War and since. At some of these, the tanks were of sufficient capacity for populations of 40,000 to 50,000.

(2) It is customary practice in installing sewage treatment plants to construct two or more of the tanks so that they may be operated in parallel. The number and size of tanks in any given project are determined by the amount of sewage to be treated, taking into consideration the probable increase in daily rate of discharge for a period of years. The tanks should have a holding capacity of one-third to one-half of the total daily flow of sewage.

p. Imhoff tank.—In many cities in Europe and America and in some Army posts the Imhoff tank renders the service corresponding to the War Department sewage treatment tank. An Imhoff tank is a two-story hydrolytic tank consisting of an upper or sedimentation chamber with steeply sloping bottoms, terminating in one or more slots through which the solids may slide when deposited in the lower or sludge digestion chamber, these slots being trapped so as to prevent the rise of gas and solids from the lower chamber. The lower chamber is provided with vents for the escape of the gases; the tank is constructed so as to facilitate the passage of the sewage quickly through the upper chamber and to prevent the flow of sewage through the digestion chamber, and is intended to be operated so that the sludge may be thoroughly decomposed, rendered practically free from offensive odor, and so filled with gas that it can be readily drawn off and dried.

q. Activated sludge process.—Activated sludge process is the agitation of a mixture of sewage with about 15 percent or more of its volume of biologically active liquid sludge (in the presence of ample atmospheric oxygen) for a sufficient period of time to coagulate a large portion of the colloidal substances, followed by sedimentation adequate for the subsidence of the sludge flocculi. The activated sludge is previously produced by aeration of successive portions of sewage and maintained in its active condition by adequate aeration by itself or in contact with sewage. It is believed that when this process is perfected it will show advantages which will warrant a more general adoption.

CHAPTER 11

HEATING

294. General.—*a.* In cold climates the heating system determines the serviceability of the building, and although there are many systems of heating the result desired in each case is the same, namely, the provision for sufficient heat to maintain an adequate temperature for healthful living and working conditions.

b. In providing sufficient heat, however, it is essential that plants be efficiently and economically operated, inasmuch as great losses are sustained yearly by the Government through lack of understanding of proper operation of heating plants. In many cases substantial economies can be effected by careful operation.

c. Practically every type of system has been employed in the heating of buildings at Army posts, and it is therefore necessary that quartermasters and utilities' officers have an understanding of the theory of heat, fuel consumption, and the various types of heating systems.

295. Composition of matter.—Matter, that is the substance of which bodies are composed, is made up of molecules. A molecule is defined as the smallest portion of matter that can exist in an independent state. Each body is composed of millions of these molecules held together by a force called cohesion. It is thought that these molecules are separated by space; that they continue in a state of motion, vibrating back and forth, with a greater or lesser velocity; and that they continue approaching each other and receding from one another.

296. Temperature.—*a.* "Temperature" is a term used to indicate how hot or cold a body is, that is, to indicate the rate of vibration of the molecules of a body. A hot body has a high temperature; a cold body, a low temperature.

b. The temperature is not a measure of the quantity of heat a body possesses. It may be considered as the measure of velocity of the molecules of a body as they vibrate to and fro, while the quantity of heat may be considered as the kinetic energy of molecules composing the body.

c. It is important to remember that temperature is not heat, but the effect of heat, and also that heat is not temperature. If one vessel contains a pint of water at a certain temperature and another contains a quart of water at the same temperature, the quart of water has absorbed more heat than the pint, and it therefore contains more heat, although its temperature is the same as that of the pint.

297. Thermometer.—Temperature is measured by an instrument called a thermometer, which is so familiar as scarcely to need description. It consists of a thin glass tube at one end of which is a bulb filled with mercury. When heated, the mercury expands in proportion to its temperature. Thermometers are graduated in different ways. In the Fahrenheit thermometer, which is generally used in this country, the point where the mercury stands when the instrument is placed in melting ice is 32°. The point indicated by the mercury when the thermometer is placed in water boiling in open air at a mean atmospheric pressure of 29.921 inches of mercury is marked 212°. The tube between these two points is divided into 180 equal parts called degrees. The Centigrade thermometer is graduated to a scale of 100 parts. In this thermometer, the freezing point of water is 0 and the boiling point 100°.

298. Measurement of heat.—Since energy is invisible it cannot be measured directly but must be measured by its effects. Heat being

a form of energy is measured by its effect in raising the temperature of water.

a. British thermal unit.—The name given to the unit of quantity of heat is British thermal unit (abbreviated B. t. u.), and it is defined as the amount of heat which will raise 1 pound of pure water from 62° to 63° F. In defining the unit of heat, it is necessary to specify the temperature of the water, because the amount of heat necessary to raise the temperature of 1 pound of water 1° varies slightly at different temperatures. This variation is so slight, however, that for most practical purposes the B. t. u. may be taken as the quantity of heat required to raise the temperature of 1 pound of water 1° without reference to any particular temperature.

b. Calorie.—In the metric system the unit is the calorie or the heat necessary to raise the temperature of a kilogram of water 1° C. at its point of maximum density.

1 B. t. u. = 0.252 calorie.
1 calorie = 3.97 B. t. u.

c. Specific heat.—Specific heat is the ratio between the amount of heat required to raise a unit weight of a substance 1° F. to the amount of heat required to raise the same weight of water 1° F. For example, it takes 1 B. t. u. to raise 1 pound of water 1° F., but it takes only 0.115 B. t. u. to raise 1 pound of iron 1° F.

299. Latent heat of evaporation.—*a.* After water is heated to the boiling point, more heat must be applied to change it into steam. This heat is called the latent heat of evaporation or simply the latent heat. The latent heat for one pound of steam, which is the number of heat units that must be supplied to one pound of water at the boiling point to change it into steam, is equal to 970.4 B. t. u. at atmospheric pressure (29.921 inches of mercury).

b. The entire amount of the latent heat is absorbed only when the pound of water has evaporated. When one-quarter of the latent heat is absorbed, ¼ pound of water is changed into steam; when one-half of the latent heat is absorbed, ½ pound of water is changed into steam; and when the entire latent heat is absorbed, the entire pound of water is changed into steam.

c. It must be firmly emphasized that the addition of the latent heat of evaporation and the consequent change of water into steam have no effect on the temperature, the steam when formed being at the same temperature as the water.

300. Total heat.—The total heat required to form a pound of steam is the sum of the heat of the water per pound and the latent

heat per pound, e. g., the total heat required to evaporate 1 pound of water at 32° temperature and at atmospheric pressure is 180 B. t. u. (in water) plus 970.4 B. t. u. (in latent heat) or a total of 1,150.4 B. t. u.

301. Transfer of heat.—When any substance is heated, there is always a tendency for the heat to spread throughout the substance and in this way to cause all parts of it to reach the same temperature. This indicates that heat may flow or be transferred from one point to another. When two bodies are placed in contact with each other the hotter body becomes cooler and the colder body hotter until finally their temperatures equalize. This observed fact proves that heat can be transferred—that it flows from the hotter body to the cooler body. Heat may be transferred from one body to another in three different ways: by radiation, conduction, and convection.

a. Radiation.—Radiation is the transfer of heat between bodies separated by a transparent medium. The heat from the sun reaches the earth by radiation. The heat felt when one sits at the side of a fireplace or radiator comes to him by radiation.

b. Conduction.—Conduction is the transfer or flow of heat from a hotter to a colder particle in contact with it. When one end of an iron rod is held in a fire the other end will soon become hot. The process by which heat travels from one end of the rod to the other is an example of transference of heat by conduction.

c. Convection.—Convection is the transfer of heat caused by a motion or circulation taking place within the body of a liquid or gas. A common example of transferring heat by convection is to be found in the hot-water system of heating. In this system the water is heated in a heater placed in the basement and rises through pipes to the radiators located in the rooms above where it loses part of its heat. Then being cooler it flows downward through other pipes to the heater.

d. Combination of methods.—In a great many cases heat is not transferred by conduction, convection, or radiation alone but rather by a combination of two or three of these methods. When a room is heated by a hot-water radiator the heat is transferred from the water to the inner surface of the radiator by conduction. It is then transferred from the inner to the outer surface by conduction through the metal of the radiator. Part of the heat which is now at the outer surface of the radiator is transferred to objects in the room by radiation. The remainder is distributed by convection currents of

the air which air is heated by contact with the radiator and then moves away to the other parts of the room where it gives up its heat by conduction or contact.

302. Conductors.—All known substances will conduct heat to a measurable extent, but the rapidity of the conduction varies greatly in different materials. Thus substances are classed as good or bad conductors according to the rapidity with which they conduct heat.

303. Insulators.—Those substances which do not allow heat to pass through them readily are said to be good insulating substances.

304. Intensity.—The law which governs the intensity of radiant heat is: The temperature is inversely proportional to the square of the distance from the source of heat. Thus, the heat which is received upon a surface 1 foot square at a distance of 5 feet diverges and covers a space of twice that width and height, having four times the area at a distance of 10 feet; the heat being spread over four times as much surface has only one-quarter the intensity.

305. Types of heating systems.—The heating systems in more common use at Army posts may be classified as follows:

a. Steam heating, one-pipe system.
b. Steam heating, two-pipe system.
c. Hot-water system, open to atmospheric pressure.
d. Hot-water system, closed to atmospheric pressure.
e. Hot-air system.

306. Classification of heating systems.—Heating systems may be classified under two general heads, direct or indirect.

a. Direct.—In the direct systems the heated surfaces are placed in the rooms to be heated. Grates, stoves, steam, and hot-water radiators are of this class.

b. Indirect.—In the indirect heating systems, the heated surfaces are placed outside of the rooms to be heated. Air is heated by passing it over steam coils or other radiating surfaces. The heated air is then conducted to the rooms by means of air ducts. Indirect systems are divided into two general classes; those in which the air circulates by gravity and those in which the air is forced to circulate by motor-driven fans or blowers. An example of the former class is the ordinary hot-air heating furnace, in which the circulation of air through the furnace and ducts is produced by the difference in temperature, and consequently in density, between the air in the hot-air ducts and the cold outside air. The fan or hot-blast class is extensively used in school houses, public buildings, and factories.

From a standpoint of ventilation this method of heating is much superior to the direct radiation method. It supplies fresh air at the requisite temperature to maintain a proper temperature in the room.

c. *Direct-indirect.*—Combinations of direct (steam or hot-water radiators) and indirect systems, known as direct-indirect, are advantageous for use in schools, churches, auditoriums, etc. By this means it is possible to regulate the ventilation properly and at the same time operate a plant more efficiently. The term "direct-indirect" is also applied to the method by which the external air is introduced into a room in such a way that it comes in contact with the radiator and, becoming heated, circulates through the room, and unless other means are provided passes out through cracks around doors and windows. This is sufficient ventilation for living rooms and offices.

307. Suitability of systems.—Steam and hot-water systems are suitable for all climates requiring heat. The hot-water system is considered better because it gives a more uniform heat and better fuel efficiency, but on the other hand the hot-water system usually exceeds the steam system in first costs. Hot-air systems are suitable for mild climates.

308. Boilers.—*a.* (1) The boilers installed in connection with small steam-heating systems are usually of the cast-iron sectional type either round or rectangular. There are few steel boilers made for small heating requirements, steel boilers being usually used for large installations of radiation exceeding 5,000 square feet. If steel boilers are used they are of the water-tube or fire-tube type of numerous designs.

(2) The cast-iron boilers take less space, are easily set, require no special foundation or brick settings, and are insulated from heat losses by a covering 1½ inches thick of asbestos cement.

(3) The capacity of low-pressure heating boilers is stated in terms of the number of square feet of direct standard column radiation which the boiler will supply at its outlet in 1 hour under recognized standard conditions.

(4) It should be noted that the rated capacity is stated as the amount of direct radiation that the boiler will supply at its outlet, so that the rated capacity of a cast-iron boiler does not provide for connecting piping.

(5) In selecting a boiler of proper capacity, it is the usual practice to add 33 percent to the amount of square feet of direct radiation, which addition is necessary to offset connecting pipe losses, and take

a boiler with the rated capacity nearest to the amount of direct radiation plus the 33 percent.

(6) In order to produce its rated capacity, there must exist sufficient intensity of draft to enable the burning of a sufficient number of pounds of coal to produce the required steam per hour.

(7) For rating steam boilers, a pressure of 2 pounds per square inch has been established; and for hot water boilers the rating is based on a temperature of 180° F. for the outgoing water and 160° F. for the water returning to the boiler.

(8) The boiler must have sufficient firebox capacity to carry the boiler for 6 to 8 hours on one charge of coal depending on the number of hours upon which the ratings have been based. Boilers rated on a basis of 8 hours are to be preferred.

b. Size of cast-iron boilers.—The following methods are used by the office of The Quartermaster General to determine the size of cast-iron boilers:

(1) *Steam.*—(*a*) For magazine type boilers (anthracite coal), installed radiation $\times 1.33 =$ boiler capacity in square feet of equivalent direct radiation.

(*b*) For hand-fired boilers (bituminous coal), installed radiation $\times 1.08 \times 1.25 =$ boiler capacity.

(*c*) For oil or gas (A. G. A. rating), installed radiation $\times 1.66$ $=$ boiler capacity.

(2) *Hot-water* (open system).—(*a*) For magazine type boilers (anthracite coal), installed radiation $\times 1.08 \times 1.25 =$ boiler capacity in square feet of equivalent direct radiation.

(*b*) For hand-fired boilers (bituminous coal), installed radiation $\times 1.33 =$ boiler capacity; combustion rate not greater than 5 pounds of coal per square foot grate area per hour.

(*c*) For oil or gas type boilers, installed radiation $\times 1.33 \times 1.08$ $=$ boiler capacity.

(3) *Hot-water* (*closed system*).—In the closed system, as installed at Army posts, the heat emission from the radiators is 200 B. t. u. per hour per square foot of direct hot-water radiation; therefore, each formula given in the hot-water open system must be again multiplied by $\frac{200}{150} = \frac{4}{3} = 1.33$ to secure the capacity for boilers used on a closed hot-water system.

c. Efficiency.—(1) The efficiency of the boiler is the ratio of the heat units absorbed by the boiler in heating water, or making steam, to the heating value of the fuel burned in a given time; that is, if

the coal has a calorific value of 12,000 B. t. u., and 6,000 B. t. u. are absorbed by the boiler, it is operating at 50-percent efficiency.

(2) The amount of steam produced depends on the B. t. u. value of the coal and the efficiency of the boiler. For example, a boiler with a rated capacity must produce enough steam at 2 pounds pressure to supply each square foot of radiation with 240 B. t. u. per hour; therefore a boiler with a rating of 1,000 square feet will supply 240,000 B. t. u. per hour.

309. Insulation.—*a.* Boilers are transformers of energy, converting other forms of energy into heat; radiators are the distributors of heat for useful purposes; and insulating materials are the retainers of heat. Or, briefly, boilers are generators; radiators are users; and insulators are reservoirs of heat.

b. It is the function of all insulating materials to prevent as much as possible the loss of heat from a heating system at all points where it is not required for useful purposes. They are conservation factors in heating systems.

c. Many different substances resist the flow of heat but comparatively few of them are well-adapted for practical use in heating plants. Those most commonly used for coverings of boilers and distributing pipe lines are magnesia, asbestos, and mineral wool, which are specially prepared in many different forms for the purpose. On irregular surfaces it is customary practice to apply the material in a plastic state so that it will come in contact with all surfaces; however, precast or sectional covering is used on all regular surfaces, especially on piping. It is very essential that all insulating materials fit the metallic surfaces closely so as to prevent the circulation of air between them.

d. Pipe coverings, settings, and insulation of boilers should be carefully maintained. To accomplish this it is necessary that they be inspected frequently. This is especially important in the case of long mains of central heating systems.

e. Pipe covering ceases to be an effective insulation when saturated with water. Most covering materials are seriously injured or their value permanently destroyed as a result of wetting. Every possible precaution therefore should be taken to keep pipe trenches and tunnels dry.

310. Effect of painting radiators.—*a. General.*—(1) The effect of painting radiators was originally determined by experiments made with a cast-iron rectangle, and, in applying paints to radiators of standard type, corrections must be made to allow for the difference

between the area of the radiating and convecting surfaces. Painting changes the radiation constant of the radiating surface but has practically no effect upon the heat lost by convection. It is therefore a surface effect, and it makes no difference what paints are placed on the radiators as a priming coat; the results are always dependent upon the last coat of paint put on the radiator.

(2) On radiators having a large proportion of radiating surface, such as pipe coils or wall coils, the effect of painting will be more marked than on four-column radiators having a comparatively small radiating surface in proportion to convecting surface. All finely ground materials have about the same radiation constant. Therefore, all paints having finely ground pigments will give about the same effect. Metals have a poor radiating effect so that any paint involving flake metal, such as bronze, will have a low radiating constant.

b. Percentage of effectivenes.—The following tabulation shows the relative effectiveness of various kinds of paint:

	Percent
Cast iron, bare	100
Painted with—	
Flat black	100
Aluminum bronze	75
Copper bronze	76
White enamel	101
Maroon japan	103
White zinc paint	98
No-lustre green enamel	96

311. Heat economy.—The economy of any heating system depends upon the completeness with which the heat value of the fuel is effectively utilized in heating the building. The principal sources of loss and the manner in which heat is utilized in a system are as follows:

a. Losses.

(1) Imperfect combustion.
(2) Sensible heat in the chimney gases.
(3) Combustible in the ash.
(4) Radiation from the boiler or furnace.
(5) Radiation from flues or piping.
(6) Losses through excessive temperatures in the building.
(7) Losses resulting from improper means of ventilation.

b. Heat utilized.

(1) Heat utilized in replacing the heat losses from the building.

(2) Heat properly utilized for ventilation.

312. Capacity of heating plant.—In all problems involved in the heating of buildings, radiation, conduction, and convection are important factors. It is by these agencies that heat is lost from a room and that such losses are restored by the different forms of heating equipment. It is obvious that in any given problem the maximum rate of loss of heat from a building determines the required capacity of the heating plant.

313. Initial step in design of heating plant.—When the air in the interior of a building is at a higher temperature than the outside air, there is a continuous flow of heat from the building. Therefore, in order to maintain a nearly constant temperature within a building under such a condition, it is necessary to supply an amount of heat which will equal the amount of heat loss. The determination of the amount of heat lost from a building per hour during the most severe conditions in the external atmosphere is the initial step in the design of a heating plant.

314. Determination of heat loss.—Different substances offer different resistances to the transmission of heat. The heat which flows through the walls, floors, ceilings, and roof of a building by conduction is transmitted from the exterior surfaces by radiation and convection. As the second factor is variable, it is impossible to determine with a high degree of precision the rate of loss from the different surfaces under variable atmospheric conditions. Wind has an important effect in increasing losses due to convection. The heat loss from a building cannot be stated accurately in any simple expression. The practical formulas which have been devised for this purpose are therefore largely empirical.

315. Coefficient of heat transmission.—One of the factors used in such formulas is the coefficient of heat transmission. This is defined as the quantity of heat expressed in terms of B. t. u. which will pass through 1 square foot of heated surface (walls, floors, or roof) per hour per degree of temperature difference between outside and inside air. The following table is not at all complete but gives values of this factor for some of the different types of building surfaces commonly found at Army posts:

TABLE OF COEFFICENTS OF HEAT TRANSMISSION FOR VARIOUS TYPES OF CONSTRUCTION PER DEGREE OF TEMPERATURE DIFFERENCE

Walls, etc.	Description	Coefficients
Plain brick walls	4 inches	0.84
Do	8 inches	.50
Do	12 inches	.36
Brick, furred and plastered	8 inches	.32
Do	12 inches	.25
Concrete walls, plain	6 inches	.79
Do	10 inches	.62
Do	16 inches	.48
Concrete walls, furred and plastered.	6 inches	.42
Do	10 inches	.37
Do	16 inches	.31
Walls of frame construction	Lath, plaster, studding, sheathing, paper, and 1-inch stucco.	.22
Do	Lath, plaster, studding, sheathing, and brick veneer.	.28
Do	Lath and plaster, studding, sheathing and siding.	.26
Doors, wood	Per square foot masonry opening	1.13
Windows, wood sash frames, and glass.	Single windows (square feet masonry opening).	1.13
Do	Double windows (storm sash)	.45
Windows, steel sash, and glass.	Per square foot of masonry opening	1.20
Partitions	Studding metal lath and plaster both sides.	.39
Do	4-inch hollow tile plastered both sides	.40
Do	4-inch gypsum tile plastered both sides.	.27
Floors and ceilings	Wood joists; metal lath and plaster one side.	.69
Do	Wood joists; metal lath and plaster one side and one thickness floor other side.	.30
Do	Wood joists; metal lath and plaster one side and double floor other side.	.21
Do	Concrete 4 inches thick	.72
Roofs	No ceiling; rafters exposed, slate or tile roof covering.	.56
Do	No ceiling; rafters exposed, composition roof covering.	.56
Do	Ceiling below; 1½ inches rigid insulation board on rafters; slate roof.	.23

NOTE.—Additional constants may be secured by consulting the "Annual Guide of the American Society of Heating and Ventilating Engineers."

316. Coefficient of leakage.—In addition to losses of heat in a building by transmission through the walls, floors, etc., heat units are

lost by the leakage of heated air through cracks around the sash and the doors. Therefore, it is necessary to ascertain the total length of cracks (in feet) around the sash and doors and multiply this length by the number of degrees of difference in temperature between the inside and outside air and by the appropriate leakage constant given below.

a. Air leakage (crack) constants.

(1) For double hung wood sash of average construction, weather-stripped, the crack constant=0.50 B. t. u. per linear foot, per degree difference in temperature per hour.

(2) For wood doors, weather-stripped, the crack constant=1.00 B. t. u., etc.

(3) For double hung wood sash of average construction, nonweather-stripped, the crack constant=1.00 B. t. u., etc.

(4) For wood doors, nonweather stripped, the crack constant =2.00 B. t. u., etc.

(5) For residential casement rolled steel sash, the crack constant =1.00 B. t. u., etc.

b. Rules to measure length of crack:

(1) For double hung sash, the length of crack equals 3 times the width plus 2 times the over-all height of the sash.

(2) For single casement sash and for doors, the crack equals 2 times the length plus 2 times the height.

(3) For double casement sash, the length of crack equals 2 times the width of a pair of sash plus 3 times the height.

317. Outside temperatures.—All heating installations should be designed so as to provide sufficient heat during the coldest weather normally anticipated for a specific locality. It is not, however, economical to install a boiler piping and radiation in a building to meet extremely low temperatures for rare occasions. As a basis of design, the United States is divided into six zones of minimum temperatures, as shown in figure 4. The minimum temperature for a particular zone should be used in calculating heating requirements for all posts in that zone.

318. Inside temperatures.—*a.* At posts, camps, and stations, it is customary to design radiators to provide—

80° F. in bathrooms.
70° F. in kitchens with electric ranges.
50° F. in kitchens with coal ranges.
70° F. in all other occupied rooms.

b. In excavated basements, the temperature is assumed to be 45° F., and in unexcavated portions under buildings the temperature is

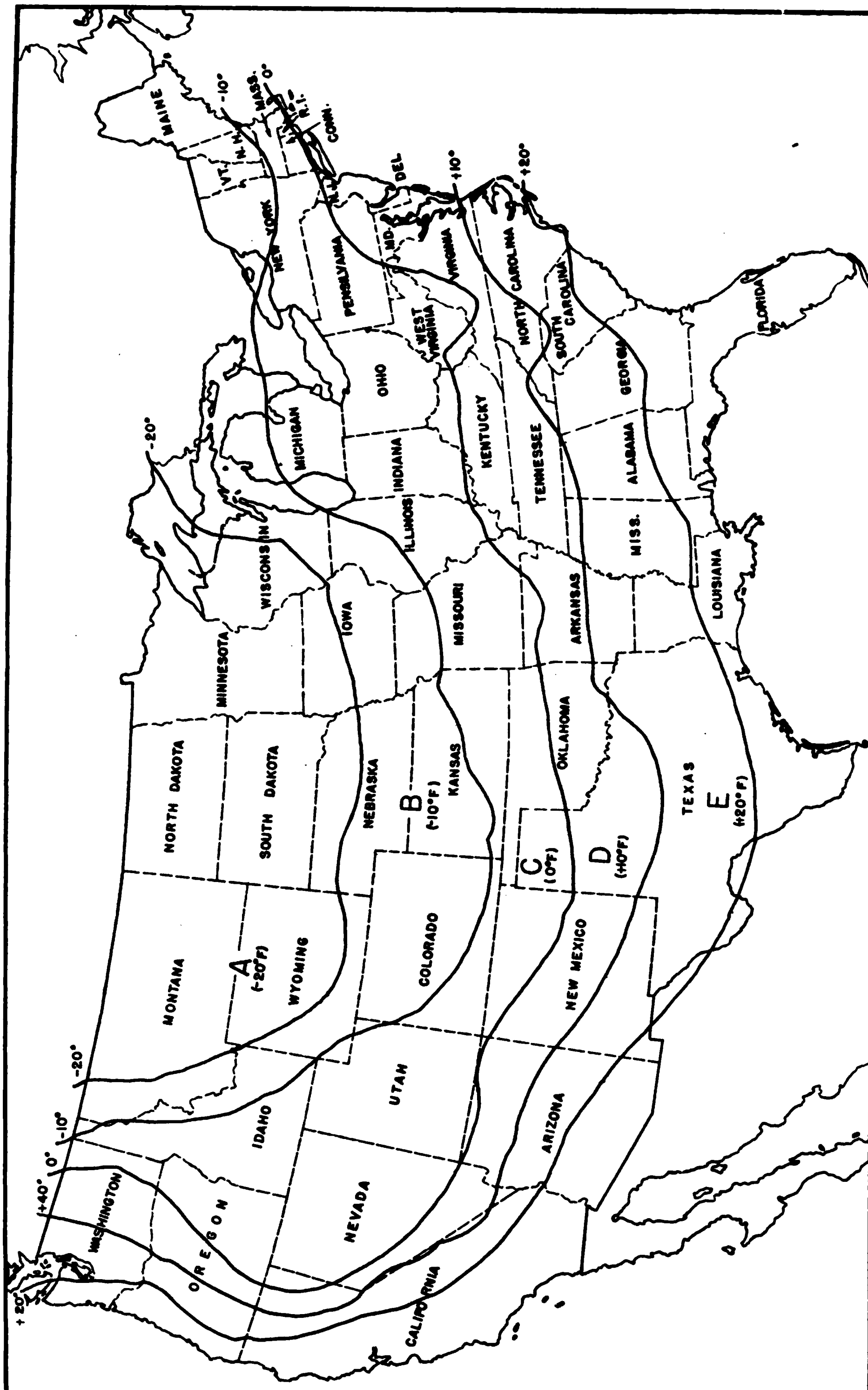


FIGURE 4.—Zone map of minimum temperature in the United States.

assumed to be 32° F., although these spaces are generally somewhat warmer.

c. In unheated attics, both the roof structure and ceiling of the top floor must be taken into consideration and the combined coefficient of transmission determined. This is somewhat complicated, and when the coefficients of transmission for the roof and ceiling are approximately the same (as obtains in Army structures), it is sufficiently accurate to assume attic temperatures to be equal to the average of the inside and outside temperatures.

319. Progressive steps in heating computations.—To compute the amount of radiation for a building we must—

a. Ascertain the minimum outside temperature that may be expected in that locality by consulting the map (fig. 4).

b. Decide upon the inside temperatures to be maintained in the various rooms. (See par. 318.)

c. Compute the heat losses in each room due to—

(1) Heat transmission through walls, floors, ceilings, door and window openings. (See par. 315.)

(2) Heat leakage through cracks around sash and doors. (See par. 316.)

(3) Total the heat losses for each room and divide it by 240 if a steam-heating system is to be installed; divide by 200 if a closed hot-water system is to be installed; and by 150 if an open hot-water system is to be used. The result will be the square feet of installed radiation required for each room.

d. Total the radiation in each room to secure the total installed radiation required in the building and substitute this figure in the proper formula in paragraph 308*b*. The result will give the size of the boiler required.

320. Fuel; fundamental principles.—*a. Combustion.*—The combustion, that is, burning, of every fuel is the chemical combination of the ingredients in the fuel with oxygen in the air. Different fuels require different quantities of air applied in different ways.

(1) One pound of coal (21 cubic inches) requires about 15 pounds (200 cubic feet) of air; that is, the volume of air is in round numbers about 16,000 times the volume of coal.

(2) One gallon of oil (7½ pounds, 231 cubic inches) requires about 142 pounds (1,866 cubic feet) of air; that is, the volume of air is in round numbers about 14,000 times the volume of oil.

(3) One cubic foot of natural gas requires from 9 to 10 cubic feet of air, and 1 cubic foot of manufactured gas from 4 to 5 cubic feet of air.

(4) Efficient combustion of fuel can be secured only by the use of

the correct amount of air applied in the right way. Since this operation is entirely in the hands of the fuel user, the importance of correct information is obvious.

(5) No general rule can be given for the exact adjustment of dampers in a heating plant but proper adjustment must be ascertained by trial with each installation.

(6) The burning of fuel with perfect combustion will produce carbon dioxide and water vapor. If the combustion is not perfect, carbon monoxide—a poisonous gas—and condensable vapors and smoke will be formed.

(7) No heating device has been nor can be made that will absorb its combustion products; hence they must be properly removed from the building by adequate flues.

(8) An opening should be provided at the base of all chimneys for occasional cleaning. Solid fuels require larger flue connections than gas or oil. When bituminous coal is used, horizontal sections of flue pipes require frequent cleaning.

(9) With gas, the large amount of steam that is formed when the gas is burned may give trouble by disintegrating the mortar lining of the ordinary chimney. This moisture is acid and will soon corrode ordinary thin black stovepipe. Only galvanized connections should be used and flues should be lined with a moisture-proof lining, preferably fire-clay flue pipes. If metal is used it should be heavy steel galvanized pipe.

b. Anthracite.—(1) This coal ignites and burns with a short yellowish blue flame and without giving off much smoke. It contains from 3 to 10 percent volatile combustible matter, which accounts for its short flame, but when ignited it gives off an intense heat owing to the combustion of the almost pure carbon of which it is composed. This coal is distinguished by its hardness, density, high specific gravity, and by its metallic luster.

(2) The standard commercial sizes are—

(*a*) Egg coal, which must pass a 2¾-inch mesh but not through a 2-inch mesh.

(*b*) Stove coal, which must pass a 2-inch mesh but not through a 1¼-inch mesh.

(*c*) Nut coal, which must pass a 1¼-inch mesh but not through a ¾-inch mesh.

(*d*) Pea coal, which must pass a ¾-inch mesh but not through a ½-inch mesh.

(*e*) Buckwheat No. 1, which must pass a ½-inch mesh but not through a ¼-inch mesh.

(*f*) Buckwheat No. 2, which must pass a ¼-inch mesh but not through a ⅛-inch mesh.

(3) The heating value of anthracite varies between 12,000 and 14,000 B. t. u. per pound.

(4) An average analysis of this coal shows it to contain fixed carbon, 89.5 percent; volatile matter, 4.5 percent; ash, 6 percent. The percentage of ash is lower in the larger sizes of coal and higher in the smaller sizes, increasing by about 1½ percent from one size to the next smaller size.

(5) The public has been taught erroneously to believe that only the so-called "domestic sizes" (egg, stove, and nut) of anthracite could be used in house heating. The small "steam sizes" (pea and buckwheat) represent 29 percent of the total amount of anthracite mined. Because the public, through lack of understanding of the facts, has been unwilling to use these, they became mere byproducts, sold below cost of production, and used in competition with bituminous coal without regard to their intrinsic value. Yet, with proper utilization methods, these steam sizes can be successfully used for house heating. If steam size is used, a cast-iron plate with 10 percent area of holes about ½ inch in diameter should be placed and cemented on top of the grate.

c. Bituminous coal.—(1) The classification of bituminous coal is made difficult by the lack of sharp lines of distinction between the different varieties. In ultimate composition it consists of carbon, 75 to 80 percent; hydrogen, 5 to 6 percent; nitrogen, 1 to 2 percent; oxygen, 4 to 20 percent; sulphur, 0.4 to 3 percent; ash, 3 to 12 percent.

(2) The principal characteristic of this coal is that it emits yellow flame and smoke when burning. In color it varies from pitch black to brown, with a resinous luster in the denser varieties and a silky luster in the less compact specimens.

(3) Five-sixths of the coal mined in the United States is bituminous or soft coal, containing a large proportion of volatile matter which produces smoke if not properly burned. This volatile matter is easily affected by heat and distills off rapidly when the coal is thrown on a fire.

(4) To consume properly bituminous coal and avoid fuel losses, sufficient air must be supplied to unite it with the volatile matter. The improper combustion of the large proportion of volatile matter may result in heat loss of from 15 to 25 percent and in addition will cause smoke and soot.

(5) The heating value of bituminous coal varies between 11,000 and 15,000 B. t. u. per pound.

d. Coke.—(1) Coke is the solid residue (carbon and ash) left

when bituminous coal is heated without access to air. It burns with a smokeless flame, has been aptly called a "man-made anthracite," and can be easily used in existing appliances as a substitute for anthracite.

(2) The coke must not be too hard. The best size is between ½ and 2 inches. The screenings should be delivered with the coke because they are needed for banking the fires.

e. Manufactured gas and natural gas.—(1) Manufactured gas is man made by "transmutation of crude, dirty, inert coal into energetic gas." Natural gas is made by nature and is transmitted to the consumer in its natural state.

(2) The heating value of natural gas is about twice that of manufactured gas; that is, it takes 2 cubic feet of manufactured gas to furnish the heating energy of 1 cubic foot of natural gas. Because of its high heating value, natural gas requires twice as much air for combustion as manufactured gas; otherwise, the two gases are handled alike in the usual household appliances.

(3) Natural gas does not have a distinctive, offensive odor like manufactured gas, which makes the detection of natural gas leaks much more difficult.

(4) The heating value of natural gas per cubic foot varies between 870 and 1,100 B. t. u. and for artificial gas between 147 and 720 B. t. u.

f. Fuel oil.—(1) The mechanisms for burning oil may be divided into two general classes:

(*a*) *Wick burners.*—These work on the same principle as the ordinary kerosene lamp. The wick by capillary attraction raises the oil from the reservoir below to the wick top where it is burned. These are feasible devices only for cook stoves, hot-water heaters, and small room heaters.

(*b*) *Atomizing or vapor burners.*—In these the oil is changed in form. It is broken up or atomized, or converted into vapor by pressure or heat or both pressure and heat. The pressure for atomizing may be secured by steam atomization or through an electric motor-driven mechanism. The heat for starting the burner is derived from alcohol or gas.

(2) Various oil burners on the market vary so largely in construction and operating details that instructions for their proper adjustment cannot be given here.

(3) The heating value of fuel oil varies between 18,000 to 21,000 B. t. u. per pound.

CHAPTER 12

REFRIGERATION

321. General.—*a.* Cold is the absence of heat. Refrigeration is the removal of heat from an object to any desired temperature and the maintenance of that temperature. It is produced by the exposure of a relatively warm media to one of lower temperature, the colder extracting and absorbing heat from the warmer.

b. Refrigeration is the reverse of generating steam. Every operation from generating the steam to using it in the engine is reversed. In the refrigerating process the condenser that is giving off heat to the atmosphere or cooling water corresponds to the boiler that is absorbing heat. The coils in the cold-storage room or ice tank are absorbing heat, while in a heating system the radiator is giving off heat. The compressor takes in low-temperature gas and discharges it as high-temperature gas. The steam engine takes in high-temperature steam and discharges it as low-temperature steam.

322. British thermal unit.—The unit of heat used in America is the British thermal unit, usually abbreviated B. t. u., which has been previously defined in paragraph 298*a*.

323. Heat, sensible and latent.—*a.* Heat is of two kinds, sensible and latent. Sensible heat is that which can be determined by a thermometer. Latent heat is the quantity or form of heat that is required to change the state of a material, for example, from a liquid to a vapor or from a solid to a liquid.

b. A pound of ice at 32° will absorb 144 heat units (B. t. u.) in changing to water at 32° F., the latent heat of the liquefaction of ice. The melting of a ton of ice or 2,000 pounds will therefore extract 288,000 heat units from the surrounding media.

324. Compresed-air refrigeration.—When air is compressed the temperature rises and it gives off heat, and when the pressure is released the air will again absorb heat. Compressed-air refrigeration is used to a large extent for refrigeration in ocean-going steam vessels. The system is operated by compressing air to a high pressure, cooling it by application of water, and expanding it in the room to be refrigerated. Use of compressed-air machines is limited because they are of uneconomical operation.

325. Fluids for refrigeration.—All fluids in passing to a vapor will absorb heat. Under normal atmospheric pressure, the amount of heat absorbed is definite and unvarying for each class or kind of fluid, but it increases or diminishes as pressure on the fluid is increased or diminished. A fluid to be adaptable for refrigeration purposes must have a boiling point lower than the desired temperature in the refrigerated area. Many fluids have been used for refrigerating purposes, the principal ones being ether, alcohol, carbonic acid, ammonia, and several mixed fluids. Not all of these have been practical commercially, some being dangerous to handle and others requiring too high a pressure.

a. Freon.—(1) The chemical name for this refrigerant is dichlorodifluoromethane (more commonly known as freon–12). It was introduced to refrigerating industry about 1931 after intensive chemical research and experimentation. Because of its advantages it is rapidly being adopted by manufacturers for use in small household refrigeration units as well as for large industrial plants.

(2) In view of the many desirable qualities of freon as a refrigerant, it may eventually replace other refrigerants now being used.

b. Carbon dioxide.—Carbon dioxide or carbonic acid gas is used as a refrigerating agent in some systems. It is a gas which is liquefiable at certain temperatures and pressures but requires a much higher pressure than ammonia and for that reason has not met with as much favor as ammonia. Its advantage lies in the fact that it is nonpoison-

ous, and breaks in the system are not attended by the dangers which such accidents produce in an ammonia system.

c. Sulphur dioxide.—Sulphur dioxide is a colorless gas having a very strong odor of burning sulphur. It supports neither respiration nor combustion and is about 24 times heavier than air. It liquefies under atmospheric pressure at 14° F. It is an oily liquid, and no lubrication is required in the compressor, which simplifies the machine.

d. Ammonia.—Until the introduction of freon, ammonia was the most practical medium for refrigeration, and it is still in common use in the older existing refrigerating and ice-making plants at numerous Army posts. In the small household refrigerators, however, the other refrigerants mentioned above are generally used. Ammonia is a colorless gas with a characteristic pungent odor (hartshorn) and a marked alkaline taste. It has a specific gravity of 8.5 (hydrogen being 1) and is lighter than air. It burns in oxygen, producing water and nitrogen, and is a powerful base combining with all acids to form salts. A drum of anhydrous ammonia holds between 100 and 115 pounds. It has no action on iron or steel but does attack copper and alloys. Ammonia gas must not be breathed.

326. Types of ammonia systems.—There are two distinct classes of ammonia systems as follows:

a. Absorption system.—This system is based on the fact that ammonia is the most soluble of gases; one volume of water at ordinary temperatures dissolving over 800 volumes of ammonia gas. However, as soon as the solution is heated, practically the entire amount of ammonia gas is released from the solution.

b. Compression system.—This system is based on the fact that the boiling point of liquid ammonia can be varied between wide limits at comparatively medium pressures as indicated in the tabulation below:

Gage pressure, pounds per square inch	*Temperature, boiling point ° F.*
12.22	5
15.67	0
19.46	5
23.64	10
38.73	25
51.22	35
114.49	70
139.40	80
167.92	90

327. Compression system.—*a.* In the compression system, the liquid ammonia is expanded into a gas in the expansion chamber, in which process it absorbs heat; in other words, produces cold or refrigeration. The cold expanded gas is next drawn from the expansion coils by the suction of a compressor pump and compressed at a pressure that will enable it to give off heat. After compressing, the now hot gas is forced into the condenser.

b. The condenser is a series of coils over which a constant flow of water pours. The hot gas gives up to the water an amount of heat equivalent to that absorbed in the expansion chamber and in doing so is reduced from a gas to a liquid. In this condition it passes to the liquid ammonia receiver, where it is available for return to the expansion chamber as needed.

c. Figure 5 shows a typical lay-out of an ammonia compression plant for ice making and refrigeration; also included are general instructions pertaining to operation of such a plant.

328. Absorption system.—*a.* The absorption ammonia system differs from the compression system in that the expanded gas is absorbed by water, later to be driven from this aqua ammonia by distillation, after which the hot gas is forced to the condenser. From this point the cycle is the same as that of the compression system.

b. The absorption system is said to be a little more reliable than the compression system where low temperatures are desired. However, the compression system is more popular because it can be used under more varying conditions than the other. The compressor and condenser have nothing to do with refrigeration proper. They simply make it possible to save and reuse the ammonia or other refrigerating agent. The real work of refrigeration takes place in the expansion coils.

329. Stages in compression cycle.—There are three stages in the compression cycle as follows:

a. Compression.—The refrigerating or heat-absorbing agent is subjected to pressure so that it passes to the second or condensing stage; its temperature is then reduced and it becames a liquid.

b. Condensation.—The reduction of temperature is brought about by water which carries away the latent heat set free by the liquefaction of the refrigerating agent. This is accomplished because, when compressed, the temperature of the gas rises to a point higher than that of the cooling water.

c. Expansion.—The third stage occurs when the liquefied gas is admitted to a series of coils of pipe and suddenly relieved from

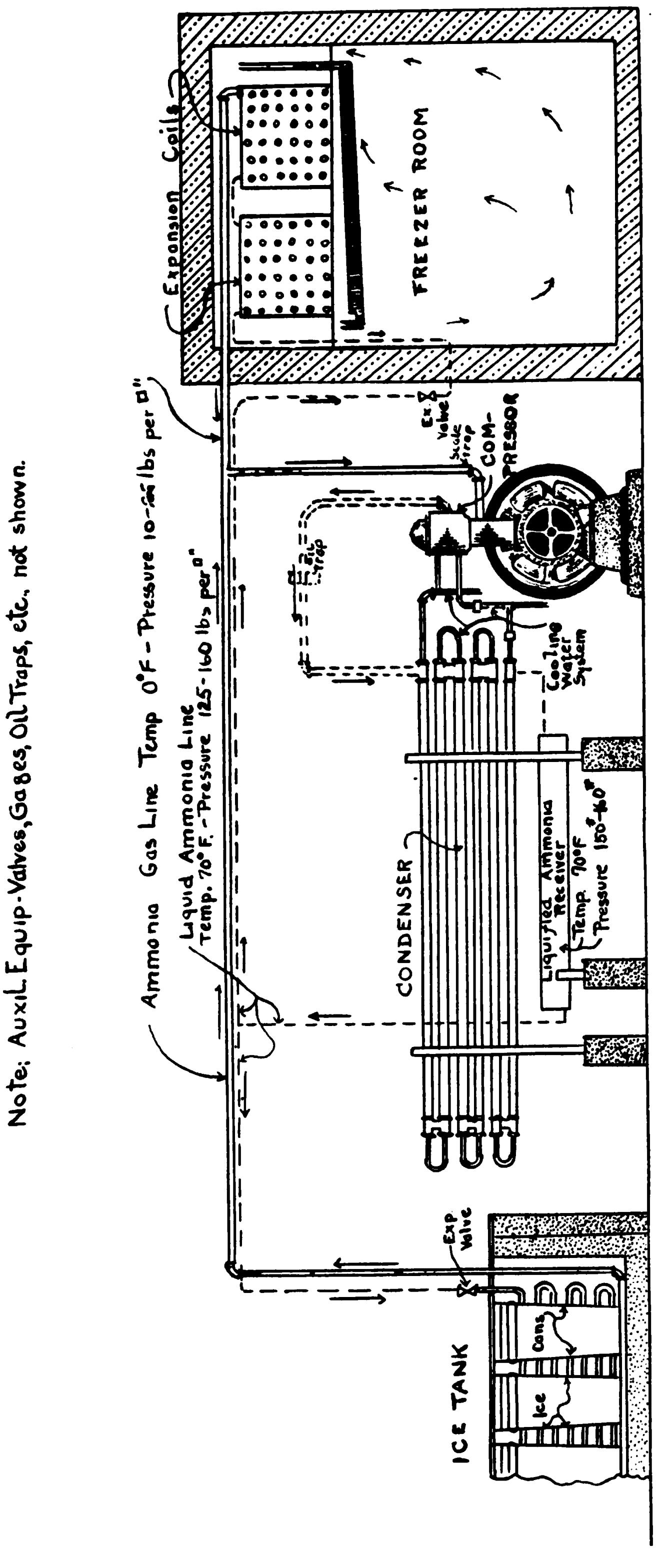


FIGURE 5.—Ice making and refrigerating machinery.

NOTE.—Auxiliary equipment, such as valves, gages, oil traps, etc., are not shown.

pressure. It then expands into a gas and must take up a quantity of heat which becomes latent, the amount of heat being equal to the amount it has just given up to the cooling water in the condenser.

330. Changes in temperature.—Ammonia gas enters the compressor at near zero temperature and leaves at 220° or higher, so that the heat in the large amount of gas has been literally squeezed into a small space and then forced through the condenser coils, which are surrounded by running water that absorbs and carries away the heat from the gas.

331. Function of the condenser.—The function of the condenser is to liquefy the ammonia gas as it is discharged from the compressor, and the work done in the condenser is the taking up of the latent heat of vaporization by the water.

332. Direct expansion method.—For refrigerating purposes, the refrigeration medium (ammonia) may be applied directly or indirectly to the chamber to be refrigerated. In the first method, known as "direct expansion," the liquid ammonia is discharged into coils in the walls or ceiling of the room where, released from pressure, it boils violently, absorbing heat from the air of the chamber, and changes from a liquid to a vapor. The avidity of ammonia for heat renders it of practicable use by direct expansion only in rooms (freezers) where low temperatures are desired.

333. Brine method.—*a. Use for maintaining temperatures above freezing.*—In chill rooms and coolers where temperatures above freezing are maintained, more satisfactory and economical results are obtained by using brine as an intermediate refrigerating medium. This is the method in use in practically all meat coolers and chill rooms, large and small. In this method the brine is chilled to the desired temperature by contact with coils in which ammonia is expanded and the chilled brine then circulated through the room to be refrigerated.

b. Equipment.—The most modern equipment for brine cooling consists of a double pipe brine cooler which is usually made of a 2-inch brine pipe inside and a 3-inch outside pipe, the ammonia being expanded in the space between the two pipes and the brine circulating through the inner pipe in a direction counter to the flow of the ammonia. Such a brine cooler, 12 pipes high and 18 feet long, is rated at 15 tons' refrigerating capacity. The entire equipment is usually installed in compact form, covered, and well-insulated to prevent loss of efficiency.

c. Kinds of brine.—Two kinds of brine are used, one a solution of sodium chloride, or common salt, in water; the other a solution of

calcium chloride. Salt brine is used where the temperature to be maintained is not below 6° F. It cannot be used in a pipe cooler because it freezes too readily. Calcium chloride brine is used where lower temperatures are desired or where a pipe-cooling system is installed.

d. Circulating brine.—Various methods are in use for circulating the chilled brine through the coolers.

(1) *Cellar method.*—In meat-curing cellars, the brine is circulated almost entirely through closed coils placed upon the walls or ceilings of the rooms.

(2) *Curtain or sheet method.*—In many hog and beef chill rooms, the curtain or sheet method is used. Here the brine flows into an open trough from which it trickles down upon a sheet suspended on edge beneath the trough.

(3) *Spray brine method.*—The newest and commonly used method for chill rooms is the spray brine system in which the brine is ejected in a fine spray from spray heads attached to the brine pipe.

(4) *Freezer method.*—In freezers the brine is circulated through closed pipes placed near the ceiling. In some freezing rooms they are arranged along the walls in the form of shelves.

e. Refrigerating medium in loft.—(1) In practically all modern chill rooms the refrigerating medium is placed in a loft at the top of the room with open passageways at each side. When closed coils are used these are placed in stands. In the sheet method the sheets are stretched from side to side of the loft. In the spray brine method, the spray heads are so arranged as to allow the spray to reach all parts of the loft.

(2) In the last two methods the brine falls to the floor of the loft where it is collected and pumped back to a brine tank to be chilled again and reused. The floor of the loft, which is also the ceiling of the chill room, slants from side to side of the room; for example, in a chill room 20 feet wide the floor of the loft will be approximately 8 to 12 inches lower on one side than on the other. This arrangement greatly facilitates air circulation.

334. Rating of plants.—*a.* Refrigerating plants are always rated in tons of capacity, for example, a given number of tons of refrigeration per day of 24 hours. Before the advent of refrigerating machinery, ice had been used for cooling and it was natural to rate the capacity of a machine in terms equivalent to tons of melting ice. Therefore, a 10-ton machine will produce refrigeration equivalent to the melting of 10 tons of ice in 24 hours. The melting of 1 ton

of ice has been shown to be equivalent to the removal of 288,000 B. t. u. of heat.

b. When refrigerating machines are used for making ice, it requires 1¾ tons of refrigeration to make a ton of ice; that is, 1 ton of ice is equivalent to 1.75 tons of refrigeration, or 1 ton of refrigeration is equal to 0.572 ton of ice. A refrigerating machine rated at 15 tons can be depended upon for 8.58 tons of ice.

335. Insulation.—*a. Importance.*—The efficiency of a refrigerating system does not depend upon the cold-making machinery alone. There are other factors which are equally important, among which are the insulation of the room to be refrigerated, the humidity, circulation of air, etc. Insulation of the walls, ceiling, and floors of a cold-storage room is necessary to prevent absorption of heat from the outside. Good insulating material should be a nonconductor of heat, stable and permanent, free from capillary attraction or affinity for moisture, and practically fireproof. Very few materials meet all of these requirements.

b. Insulating Materials.—(1) *Installation.*—Insulating materials in common use are granulated cork, ground redwood bark, mineral wool, hair felt, hollow tile, waterproof paper, shavings, pumice, dead-air space, etc. Of whatever material the insulation is made, its value depends largely upon the efficiency of its installation. The outer and inner surfaces are always waterproofed, cement being the usual finishing material.

(2) *Granulated cork.*—Granulated cork is by far the best known insulating material and the one in common use. It is prepared in sheets, the granules being cemented together by baking or by the use of cement. In this form, if properly installed, it more nearly meets all the requirements of a perfect insulating material. The thickness of insulating necessarily depends upon the temperature to be desired, the exposure of the walls to external heat, etc.

(3) *Hair felt.*—Brine pipes running outside of the refrigerated space require proper insulation. Hair felt with outer waterproofed covering is usually used for this purpose.

c. Doors.—The tightness of doors and other openings into cold-storage rooms is a big factor in the efficiency of insulation.

336. Air circulation.—*a.* Air circulation in a cold-storage room is essential for effective refrigeration. This is particularly true when warm materials such as fresh beef are placed in a chill room. The air, coming into immediate contact with the beef, extracts heat and moisture from it, and the air soon loses its capacity for further

absorption of either; that is, the meat and the surrounding air reach a mean temperature which may be considerably higher than that desired for proper preservation of the beef.

b. As air becomes warmed, its specific gravity is reduced and it is forced upward by colder air of greater specific gravity. The warm air rises until it reaches the sloping ceiling, along which it flows until it reaches the air shaft to the loft above. In the loft, it comes in contact with the cold closed brine coils, the brine-saturated sheets, or the brine spray, where it gives up its heat and becomes of lower density. The cold dense air settles and flows along the sloping floor of the loft to the air shaft opposite the one that carried the warm air upward. It then flows downward and settles to the floor of the chill room to replace the warmer air in contact with the meat, thus completing the cycle.

c. Air circulation in modern coolers and freezers is maintained almost entirely by gravity. In some cases fans are used to aid circulation. In freezers, the brine or direct expansion coils are placed in stands directly beneath the ceiling. Here the warmer air rises directly to the coils, is chilled, and flows back again.

337. Saturation or dew point.—*a.* The amount of moisture which air can contain varies with the temperature. The point at which air can hold no more moisture is called the saturation or dew point. In determining the relative humidity of the air, the point of saturation is designated as 100, and the degree of saturation of the atmosphere is called its relative humidity.

b. The capacity of air for moisture is increased or decreased as its temperature increases or decreases. Air which is saturated with moisture at 30° F., when raised in temperature to 40° F., holds but 68 percent of its total capacity. Inversely, if saturated air at 40° F. is reduced in temperature to 30° F., moisture will be precipitated.

338. Humidity of air.—*a. How determined.*—The humidity of air is determined by use of a humidity hygrometer or psychrometer. The latter is the instrument in most general use. It consists of two thermometers mounted on a frame. The bulb of one of these thermometers is encased in muslin and when in operation is kept wet, while the other bulb remains dry. When in use the evaporation of water from the wet bulb carries away heat, resulting in the registration of a lower temperature by the wet-bulb thermometer than by the other. The difference in temperature registered by the two thermometers indicates the relative humidity of the air in the room. Carefully prepared tables are used for readily computing this

humidity. The psychrometer does not produce satisfactory results at room temperatures below 29° F. because the water on the wet bulb freezes and makes results inaccurate.

b. Control of humidity.—(1) *Natural means.*—Humidity in refrigerated rooms is controlled largely by natural means. When carcasses of freshly killed animals are run into a chill room, a cloud of steam arises. This is due to the fact that as the air in contact with the carcasses becomes warm, its affinity for moisture increases. This warm air, then, as it rises carries with it the moisture from the surface of the carcasses. As the air again becomes cooled by contact with the cold brine, it loses its power to hold the moisture which is precipitated upon the coils or in the spray. In curing cellars where the coils are frequently placed under the ceiling, the precipitation of moisture upon the coils results in a drip, and this is collected in drip pans placed beneath the coils. In freezers the moisture is precipitated upon the coils in the form of ice. If not removed, this ice will become so thick as seriously to retard refrigeration.

(2) *Absorbents.*—In refrigerated rooms where the refrigerating coils cannot dispose of the excess moisture, absorbents are frequently used, the most common being unslaked lime and calcium chloride. The latter is highly deliquescent and is most favored. Its use will keep the average cold-storage room dry.

339. Ventilation.—Very few cold-storage rooms are equipped with special facilities for ventilation, relying for the most part for fresh air upon the opening and closing of outside doors. In such rooms, the air would soon become foul were it not for the fact that most of the impurities in the air are carried by the moisture. When this is precipitated upon the pipes and absorbed by calcium chloride, most of the impurities are removed. Ventilating systems, in order to prevent too great a disturbance of room temperatures, must bring the fresh air introduced to approximately the temperature of the room.

340. Compressor pressure.—In operating a refrigerating plant, it is important to bear in mind that the lower the pressure which the compressor works against, the lower will be the power cost for operating the compressor. This pressure is determined by the temperature of the cooling water (see par. 326*b*), provided the condenser is large enough and clean. Therefore, particular attention to the temperature of the cooling water is of great importance.

341. Condenser tubes.—Particular stress is also laid on the importance of keeping condenser tubes clean. Double pipe condenser tubes should have a scraper run through them as often as it is

found necessary to keep the scale off the inside of the tubes. Atmospheric condensers usually can be cleaned with a wire brush. The number of times necessary to scrape condensers during the year will depend upon the kind of water used for condensing purposes. Dirty condensers insulate the pipe and increase the head pressure, which in turn increases the horsepower necessary to produce the required refrigeration. It is sometimes advisable to paint atmospheric condensers, but only a thin coat of paint should be applied. Heavy coats of paint also insulate the condenser and cause the head pressure to rise.

342. Expansion coils.—Care should be taken to inspect the cooling coils in refrigeration plants at frequent intervals. The efficiency of the cooling system is reduced by the accumulation of ice and snow. This acts as insulation and corresponds to magnesium pipe covering in both looks and effect. Thus, the pipes are prevented from absorbing heat. Since the snow is the result of condensation of moisture in the cold rooms, and this condensation dries the air, storage conditions are made better and more sanitary. The snow will be formed more rapidly if the colder pipe surface is exposed, and thus a higher rate of drying will be secured. Another result of the accumulation of snow on the pipes is the additional load placed on the supports for the coils. Therefore, snow and ice should never be allowed to accumulate so that it will exceed an inch in thickness, and it should be kept less if practicable. Periodic cleaning of each part of the system is necessary.

343. Ice manufacture.—*a.* Ice is made by freezing water in rectangular tanks holding 200 to 400 pounds of finished ice. These tanks are filled with the water to be frozen and lowered into tanks of calcium chloride brine. The brine is maintained at a temperature of 15° F. by ammonia expansion coils. As heat is extracted from the water, ice crystals form on the inner surface of the tank, the process continuing until the entire water content of the tank is frozen. The tank containing the cake of ice is then drawn out by means of a block and tackle suspended from an overhead rail and run to the discharging point. Here the ice in the tanks is allowed to stand for several minutes to temper, in order to prevent shattering when the tanks are lowered into warm water. The tank is then lowered into a vat of warm water for a moment to cause the ice in close contact with the sides to melt, thus allowing the cake of ice to slide out of its tank when removed from the warm water bath and inverted.

b. The length of time required to freeze a tank of water depends

upon the temperature of the brine and the purity of the water, but under average conditions approximately 36 to 48 hours are required.

344. Water.—Pure water will make pure clear ice if properly frozen; impure water will not. The various impurities in the water will show up as white or discolored particles of deposit, and the inclosed air or other gases will show up as tiny bubbles or air needles. In the process of distilling water all the impurities are left behind and the condensed steam is pure. Ice made from distilled water is perfectly clear.

345. Air agitation.—*a. Purpose.*—As unagitated raw water freezes, the ice crystals which form are pure and clear. However, the mineral constituents and other impurities in the water separate and are deposited upon the ice crystals as tiny white or colored particles, giving the cake of ice an opaque appearance which ice men refer to as "tombstone" ice. When air agitation is used, however, the air bubbling through the water gives the current of water a gentle agitation which washes the face of the ice as it freezes, carrying toward the center of the tank these particles of frozen-out impurities. Thus the water in the center of the tank becomes filled with these impurities.

b. Core.—The final freezing of this impure "core" as it is called results in an opaque, dirty center in the cake of otherwise pure ice. To prevent this, raw-water ice manufacturers pump out this core of impure water and replace it with clean water and cracked ice.

346. Troublesome impurities.—The most troublesome impurities in water used in raw water ice making are bicarbonate of lime and magnesia, sometimes referred to as dissolved limestone. When not removed from the water by pumping the core, or otherwise, they form a white slimy deposit on the ice as it melts. A way to remove these impurities from the water before freezing has recently been devised. It consists of the addition of lime to the water in exact amount, depending upon the quantity of these impurities. This changes the soluble bicarbonates to insoluble form and they are precipitated. This process lessens the labors of the ice maker because it avoids the necessity of pumping the core.

CHAPTER 13

ELECTRICITY

347. General.—*a.* The study of electricity can easily develop into a most fascinating pursuit, but owing to the magnitude of the subject it is necessary to confine this discussion to a bare outline which may be followed in any direction with considerable interest on the part of those who desire it. No endeavor will be made to mention in detail the various branches. Many activities of a utilities officer have to do with electricity. For example, quarters or barracks must have wiring and fixtures for electric lighting. If the quarters are for an officer and a study of conditions warrants the use of electricity for cooking, the building is designed to provide this latest refinement which dispenses with much of the inconvenience of the kitchen. We install a water-pumping plant and almost invariably find that electricity will furnish the power; the same may be true of the ice and refrigeration plants. Our laundries in nearly all cases are electrically operated; our hospitals must be provided with wiring which will accommodate the many electric devices which are now considered so essential in treatment of the sick; and so on.

b. It follows that officers whose duties have to do with utilities functions should be prepared with more than a slight knowledge of this subject to be able to handle successfully the problems which present themselves or are discovered in the proper supervision and administration of utilities. In the study of the use of electric energy for pumping water, for driving machinery, for lighting our buildings,

etc., we gradually become accustomed to thinking in terms of money which eventually is transformed into the necessary activities, so that we readily translate the medium into terms of cost per thousand gallons of water, the cost per horsepower delivered to a shafting, and the cost of securing the necessary illumination in buildings.

348. History.—The history of this medium is of much interest as is also its relation to the electron theory which is now generally accepted. However, for further reference along these lines, attention is invited to The Electron Theory by Fournier; Modern Views of Matter by Lodge; Modern Views of Electricity by Lodge.

349. Electrical units.—*a. General.*—For direct current, the well-known flow of water analogy can be used to illustrate electrical principles. Pressure in a water system is measured in pounds, in an electrical system in volts; in either case the quantity of flow varies with the pressure. In hydraulics, the gallon is a definite quantity; in electricity, the ampere is likewise a definite quantity; neither is the symbol of a rate of flow. The rate of flow in hydraulics is gallons (or perhaps cubic feet) per minute; in electricity it is amperes per second, and this rate of flow has its own name—one ampere per second, or its equivalent, is a coulomb. A water pipe retards the flow of water by its internal friction, this is measured in pounds per foot or per 100 feet, etc. A wire carrying electric current likewise impedes the flow of current, the amount of resistance differing according to the material of which the wire is made; the unit of resistance is known as the ohm. In a water pipe, the longer the pipe, the greater the total resistance; and in an electric wire, the longer it is, the greater the resistance. Just as using a larger size of pipe will reduce the friction, so using a larger size wire will reduce the resistance. At this point, the analogy between the flow of water and of electricity ends. We find that there is a vast difference between the effects of increasing the pressure on a water pipe and increasing the pressure (voltage) on an electrical conductor. In a water system, we find that the friction losses are lowest when the water moves slowly through the pipe (that is, under low pressure). When current flows through a wire of given length, there is always a definite relationship between resistance (ohms), pressure (volts), and current (amperes), expressed thus: amperes equal voltage divided by resistance. Thus, increasing the voltage reduces the resistance; or to state it another way, increasing the voltage makes it possible to deliver the same quantity of electricity over a smaller wire or a larger quantity of electricity over the same wire. This principle is made use of in alternating current trans-

mission by "stepping up" or increasing the voltage over a transmission line and, if the voltage is too great for use at the point of delivery, the current is then "stepped down" to a safer value. This can only be done with alternating current, because it can be used for "inducing" a secondary current of higher or lower voltage when a coil carrying a flow of electricity is placed within or without another coil. Direct current cannot be used in this way.

b. Standardization.—In order that proper measurements might be taken, it was necessary that certain electrical units be adopted. These are now becoming carefully standardized throughout the world and are used in the same way in most countries. The units commonly used are the volt, ampere, ohm, and watt.

c. Electromotive force.—Electromotive force, abbreviated e. m. f., and sometimes called voltage, electric pressure, or difference of potential, is used to designate the "push" which moves or tends to move electrons from one place to another; in other words, that which causes electricity to flow. Note that voltage or e. m. f. is not electricity; it is the pressure that causes electricity to flow. There may be great electrical pressure, but if the circuit is not closed there can be no flow or current of electricity.

d. Volt.—The volt is the unit of electric pressure. It was named after Volta, an Italian scientist. The unit of electromotive force is known as the international volt, which is the electromotive force that, steadily applied to a conductor whose resistance is one international ohm, will produce a current of an international ampere. The volt corresponds to pressure.

e. Ampere.—The ampere is the practical unit of electric current flow. It was named after the French scientist, Ampere. It is defined as the practical equivalent of the unvarying current which, when passed through a solution of nitrate of silver in water in accordance with standard specifications, deposits silver at the rate of .001118 gram per second. If a pressure of 1 volt be impressed on a closed circuit having a resistance of 1 ohm, then 1 ampere will flow through the circuit. Currents of water running through pipes are measured by the amount of water that flows through the pipe in a second; thus, we say "1 gal. per sec.", "10 gal. per sec.", and the like. In a similar manner, flows of current of electricity are measured by the amount of electricity which flows through a conductor in a second. Thus, we say "10 amperes per sec.", and the like; an ampere being a certain quantity of electricity just as a gallon is a certain quantity of water. The term coulomb has been applied to a rate of flow of an ampere

per second. Hence, a current of 1 coulomb is a current flowing at the rate of 1 ampere per second.

g. Ohm.—The ohm is the unit of resistance or that internal force which holds back the current in a conductor. It was named after the German scientist, Ohm. It is defined as the resistance offered by a column of pure mercury at 0° C. of uniform cross section 106.3 centimeters long and 14.45 grams in weight. Conductivity is the opposite of resistivity. This unit corresponds to a retarding effect.

g. Watt.—The watt is the unit of energy or work. It was named after the Scottish inventor, Watt. In a direct current circuit, it represents the amount of power when the current flowing is 1 ampere and the e. m. f. is 1 volt. In an alternating current circuit, the voltage and the current are constantly changing in value, so that it is necessary to compute the power from their effective values, which are the values they would have if reduced to terms of constant current and voltage.

h. Kilowatt.—The kilowatt is a term to express a thousand watts. In changing from horsepower to watts, it should be remembered that 1 horsepower equals 746 watts.

350. Ohm's Law.—*a.* The formula used more than any other in electrical measurements is called Ohm's Law. For direct currents, it is expressed thus:

$$\text{amperes (current)} = \frac{\text{volts (pressure)}}{\text{ohms (resistance)}}$$

This may be converted to various forms, for example:

$$\text{volts} = \text{amperes} \times \text{ohms}$$

$$\text{ohms} = \frac{\text{volts}}{\text{amperes}}$$

b. In alternating currents the above formula may appear in a much more complicated form but the basis will be the same.

351. Direct current.—*a.* The electric energy used in ordinary power and lighting may be either direct or alternating current. By direct current we mean that the current travels in one direction only. The current from any kind of battery is direct. Where an electric generator has a commutator and brushes, the current is direct because it always flows from the positive brush around through the circuit to the negative brush.

b. For power work, direct current is used for short distances only at shops or factories where there is need for machine tools to operate at different speeds. It is also used for electric plating, the electrolytic production of aluminum, and small installations.

352. Alternating current.—*a.* With the beginning of the present century the use of alternating current has developed rapidly. In describing alternating current for any purpose, it is necessary to state the—

(1) Number of phases.
(2) Number of cycles.
(3) Voltage.
(4) Power factor.

b. Ordinarily, alternating current is three-phase, but it may be single-phase, 2-phase, or polyphase. An easy way to visualize this is to think of a single-cylinder engine, 2-cylinder or 3-cylinder. In the last case the cranks are 120° apart, so that there are no dead centers as would be the case in a single-cylinder engine.

c. By alternating current, we mean that the current flows in one direction at a certain instant, then dies down to zero and flows in the opposite direction. Frequency of an alternating current is the number of complete reversals or cycles of the current per second. Ordinarily, most commercial current is 60-cycle; this means that the current makes 60 complete reverses or changes per second.

d. The pressure or voltage is the same used for direct current except that effective values are used.

353. Three-phase circuit.—*a.* In the case of a 3-phase circuit, the total power will be greater than for a single-phase circuit by the factor which is the square root of three, or 1.73; therefore, the watts delivered in a 3-phase circuit will be equal to volts multiplied by amperes times the constant 1.73, times the power factor. (Explanation of the term "power factor" is too involved for purposes of this manual; see any good textbook on electrical engineering.)

b. The units above mentioned are instantaneous values like the flow of water in gallons per minute. Ordinarily, what concerns the quartermaster most will be the amount of the bills to be paid at the end of the month.

c. The unit quantity of electricity used for commercial purposes is the kilowatt-hour. It means the total quantity of electricity used in 1 hour, when the rate of flow remains constant at 1 kilowatt.

354. Transformers.—*a.* The transformer is a device (operating on the principle of mutual induction) by which the energy in an alternating current circuit may be received at one voltage and delivered at a higher or lower voltage. It is really an alternating current induction coil. A transformer is one of the most important

electrical devices. It is remarkably simple in elementary principle and in construction and has no moving parts. It makes use of the principle that an electric current creates a tension in the surrounding ether. This is known as its "magnetic field." The field can be strengthened by arranging the conductor in the form of a spiral or coil, and it can be further strengthened or concentrated if an iron core is placed within the field to afford an easy path for the field. If the values of current and voltage vary, as they do constantly in an alternating current circuit, the field will also vary, its impulses roughly resembling the waves set up by throwing a stone in a still pond. If we call a circuit which receives its current from a generator a primary circuit, and if we introduce within its field a second closed circuit known as a secondary circuit, which could be another coil superimposed on the first, then each wave from the primary will cut the secondary and will induce in it a secondary current which will have the same power value (neglecting transformer losses) as that of the primary. The current and voltage may be and almost invariably are different from those of the primary, but the power value will be the same. These differing values are brought about by varying the number of turns in the primary and secondary coils; thus, if there are 10 times as many turns in the secondary coil as in the primary, the voltage in the secondary will be 10 times as great as in the primary, but the current will be one-tenth as much. Since it is the current which causes resistance in a conductor, increasing the voltage and reducing the current make it possible to use a smaller conductor for a given amount of power.

b. If electric energy is to be transmitted with economy over any considerable distance, the transmission voltage must be high so that the line losses will be minimum. However, it is neither practicable nor desirable to utilize high voltage electrical energy for electric lamps, motors, and other receiving appliances. Furthermore, it is not practicable to generate electrical energy at the high voltages which must be used for transmitting large amounts of energy over great distances. Therefore, where the energy is generated at a low voltage, a step-up transformer is used for raising the generator voltage to one suitable for energy transmission, and then a step-down transformer is applied for again decreasing the voltage to one suitable for utilization.

c. The three principal parts of a transformer are—

(1) An iron core which provides a circuit of low reluctance for the magnetic flux.

(2) The primary winding which receives the energy from the supply circuit.

(3) The secondary winding which receives energy by induction from the primary and delivers it to the secondary circuit.

The ratio of the number of primary turns to the number of secondary turns around the core determines the ratio of the primary to the secondary voltage. The losses in a properly designed transformer are very small. Transformer losses continue at all times while the transformer is connected in a circuit, even though no energy is being utilized from the particular transformer.

d. In a transformer, the ratio of voltage and amperage is inversely proportional in the primary and secondary circuits. That is, if in a step-up transformer the voltage in the secondary circuit is increased 10 times over the primary circuit, the amperage in the secondary circuit will be only one-tenth of that in the primary circuit. In the step-down transformer where the voltage is decreased, the amperage is correspondingly increased.

355. Electric rates.—*a.* The unit costs in the operation of a plant, or reasonable rates to be paid for electric current, are important considerations at any Army post. The rates now charged for electricity are very complicated. The method of computing charges for electric energy usually involves the use of complicated sliding scales of rates and other factors.

b. While there is no desire to excuse the complication of these rates, it seems advisable to consider the reason why flat rates are not usually authorized by public service commissions. For example, the construction of a large power plant, together with all the distributing lines, conduits, transformers, office buildings and supplies, involves a large outlay of capital. The interest, depreciation, obsolescence, repairs, transmission losses, collections, etc., make up a large part of the total expense which is constant, without regard to the quantity of electricity sold. Electric lighting is a very fluctuating load. There is a large peak load during the evening and a smaller peak during the morning. The station plant and equipment must be large enough to cover the greater peak, with a reserve for emergencies and repairs. In the meantime during the low periods of consumption, or the valleys as they are generally known, there is very little current used; hence, small income to pay expenses. When machines are operated at light loads the efficiency is low, but about the same amount of labor is required. For these reasons the public service companies do all they can to encourage people to use more current

during the hours of light demand. They also arrange the rates so that if the maximum peak is increased, the rates will be raised considerably, to cover the cost of operation of extra machines which are used only a short time each day.

c. In nearly all Government contracts, electricity is purchased by measurement on one primary meter and thus the benefits of reduced rates for larger quantities are secured. In the majority of cases contracts provide for a maximum demand. It is therefore important that the quartermaster and his assistants should thoroughly understand the situation and prevent unnecessary expense through carelessness or ignorance in using an unnecessary load during the hours of highest consumption.

d. Sometimes service contracts for electricity provide that the maximum demand will be based on the highest recorded measurement during a 6-month period, and that this maximum demand will be the quantity used for computing costs occurring during the following 6 months. One-half day of bad management may thus increase the rates for a whole year.

356. Power factor charges.—In a few cases rates are also based on a factor depending upon the power factor of the post circuit, but fortunately not many contracts have this added complication. It is important that the quartermaster understand whether the contract comes under the rulings of the State utilities commission or is independent.

357. Motors.—*a.* Motors for power purposes are nearly always 3-phase, 60-cycle, although single-phase motors are much used for fractional horsepowers. In the regular sizes, a standard of 220 volts has been selected, but in the larger sizes of 50 horsepower or more the voltage may be 2,300. The ordinary 3-phase motor is a very rugged and reliable piece of apparatus. It should be kept clean and the oil reservoirs well filled with good machine oil.

b. Practically all motors of five horsepower or more are equipped with starting compensators or resistances. In the squirrel-cage motors there are no electrical connections except the three wires which extend into the winding around the inner circumference of the frame. It is called the stationary armature type. The moving part, mounted on the shaft, is called the rotating field. The field is shaped like a cylinder and rotates on its longitudinal axis. The copper-bar conductors are imbedded and welded or securely connected to copper rings at each end; hence, the motor gets its name of squirrel cage. This type is essentially a constant speed motor.

c. A squirrel-cage motor is started by means of a compensator or autotransformer. It is not advisable to throw full voltage on the machine at once because it would be injurious to the motor and the lines. At first a low voltage is applied and then higher ones in steps at each increase in speed until the motor is running at the normal revolutions per minute. A squirrel-cage motor has a tendency, when starting, to jolt the incoming voltage rather severely. Some service companies will permit the use of these motors only in the smaller sizes.

d. Another form of alternating-current motor is the slip-ring type. The frame and stationary armature are practically the same as in a squirrel-cage motor. The rotating field, however, instead of having a squirrel-cage winding has a wire-wound field with connections which run down to brass collector rings called slip rings. Carbon brushes rest on these rings and are connected to an external resistance like a rheostat. When starting the motor, full voltage is thrown upon the stationary armature, but the field circuit has a large resistance between the collector rings which keeps the starting current down. Gradually this resistance is reduced as the motor increases in speed, until at full speed the collector rings are short-circuited and the motor is then practically like a squirrel-cage motor. The advantage of this motor lies in its ability to start easily under heavy load without serious effects on the incoming voltage.

358. Meters.—Nearly all meters for measuring electrical energy may be divided into three classes: indicating, graphic, and recording.

a. Indicating meters simply show the instantaneous values, and their readings are easily understood. The construction of meters need not be considered at this time. In general, alternating-current meters contain no iron while direct-current meters usually have a large permanent magnet.

b. Graphic meters make continuous record of the value of the quantity measured. This record may be on a disk chart which is changed every day, or it may be on a paper strip many feet in length which is changed only once a month. The great value of a graphic record is to enable one to investigate the variations of load and to study the problem of improvements in regulation.

c. The recording meters are ones which supply the data upon which payments are made, so it is important that the quartermaster or his assistants make accurate meter readings for themselves and be able to check the figures submitted by the electric company.

d. The recording watt-hour meter is the meter of primary importance. The moving part is essentially a small motor so constructed that it requires very little energy to operate it. The potential coil in the meter receives the voltage pressure at all times. The current coil receives the energy resulting from the instantaneous value of the current flowing. The product of these two is the wattage measured. There is an aluminum disk rotating between the poles of a permanent magnet. The eddy currents produced in this disk provide the necessary brake so that the speed of the disk will be proportional to the watts measured.

e. In the upper part of the meter, there is a series of dials which record the revolutions of the aluminum disk. These dials are connected to a train of gears so that 10 revolutions of the units dial will cause the tens dial to move one division. The same action is transferred up through the other dials.

359. Reading meters.—*a.* In reading watt-hour meters, the records should be taken from right to left, that is, from the units dial, then tens, then hundreds, to others at the left. Note the figure which the hand has passed on the units dial. Write it down. Do the same with each dial to the left, which will give the correct reading. If read from left to right, there is likelihood of error especially if the hands are not accurately set in position. It is best to mark the positions of the hands as they would appear in a photograph so that in case of dispute all the record is available. Meter books are usually marked in this manner.

b. The amount of current used each month in kilowatt-hours is found by subtracting the record of the previous month from the record of the present month. If an error is made in one month it usually corrects itself in the following month.

360. Meter factors.—*a.* Sometimes when the amount of energy used is greater than the small capacity of the meter, it is possible that the dials will not indicate the full value, and in this case there would be a caution or direction just below the dials to multiply by 10 or 5 as the case might be. The true value of the kilowatt-hours would be the difference in readings multiplied by the factor stated.

b. In some cases the voltage may be 2,300 or more, so that a potential transformer with a ratio of 20 to 1 is used; then the difference in meter readings should be multiplied by 20.

c. Frequently current transformers are used so that only a small part of the current passes through the meter. Assuming that a

current transformer has a ratio of 15 to 1, then the difference in readings of the meter from one month to another should be multiplied by 15.

d. Assume we have a meter with a potential transformer of 20 to 1 ratio and a current transformer of 8 to 1 ratio. Meter factor will then be 20 multiplied by 8 or 160.

Meter reading, Dec. 1	12,160
Meter reading, Nov. 1	10,840
Difference	1,320
1,320 multiplied by 160........kilowatt-hour	211,200

361. Electric ranges.—*a.* Within the last few years many electric ranges have been installed in various posts. It should be clearly understood that electricity cannot be used in a general manner for heating buildings economically. To accomplish this it would be necessary to obtain electricity at a cost not exceeding a small fraction of 1 cent per kilowatt-hour. The reason, however, that electric ranges can be used economically where the rates are not more than 3 or 4 cents per kilowatt-hour is that comparatively a small amount of heat is needed for cooking food. In the electric range, all the heat generated is applied directly to the dishes containing the food, and every advantage is taken of the fireless-cooker principle. The heat generated in watts is equal to the square of the current in amperes multiplied by the resistance of the unit used.

b. Generally, ranges may be divided into two classes, automatic and nonautomatic. In the latter, the operator turns on the heat and when cooking is completed turns off the heat. The automatic ranges are fitted with appliances which turn off the current, and the ranges use the stored heat thus saving electricity. In one type a clock can be set so as to throw on the current and start the cooking at the hour desired. It will allow the current to rise until the temperature has reached the desired cooking point in the oven, then the current is turned off and the cooking proceeds on the fireless-cooker principle.

c. Success depends upon intelligent operation, keeping apparatus in good repair, and following proper instructions. Only appliances which are strictly in accordance with fire underwriters' regulations should be used.

362. Electric lighting.—*a.* Since nearly all lighting in posts is now done by electricity, a few general facts on illumination are given:

b. It has been found that the ordinary requirements for lighting are—

	Foot candle
(1) For offices	3 to 5
(2) For squad rooms	2 to 4
(3) For halls and basements	1 to 2
(4) For exchanges, stores, and dining rooms	3 to 5
(5) For officers' living rooms	3 to 5
(6) For bedrooms, bathrooms, etc	3 to 4

c. A foot candle is the light given by one standard candle at a distance of 1 foot. The intensity of light varies inversely as the square of the distance; thus a lamp of 25 candlepower will give 1 foot candle at a distance of 5 feet.

d. In illumination, the thing to be remembered is that distribution should be even. If the eye has adjusted itself to a certain degree of illumination and is then subjected to a lower degree of illumination, the contrast is exaggerated. The eye should never be allowed to see the glare from a gas-filled lamp. The lamps should ordinarily be well above the line of vision. Shades should be used to direct and diffuse the light to the best advantage. Too strong a light or a glare may be just as bad for the eye as insufficient light.

e. If lamps have been improperly selected for the different sockets, a careful survey should be made in accordance with the principles of good illumination engineering practice.

f. The intensity of illumination for various rooms may be secured under normal conditions with direct lighting units, by using lamps with the wattage for each room as computed from the schedule (*g* below), which has been abstracted from AR 30-1625.

g. Wattages set forth in the following schedule are based upon direct-lighting units installed under normal conditions. In using the schedule, floor areas in square feet should be multiplied by the appropriate factor to obtain the approximate total wattage authorized. Standard lamps totaling a wattage nearest to that computed will be considered the authorized wattage for a building. This authorized wattage for each building will then be multiplied by the appropriate

factor appearing in AR 30-1620 to determine the standard quantity of light for the building for which allowance is being computed.

	Watts per square foot floor area
Individual quarters:	
Living rooms, dining rooms, baths, and kitchens	.80
Bedrooms	.40
Halls, porches, etc	.25
Storerooms, basements, closets, etc	.15
Barracks, hospitals, etc.:	
Offices, day and recreation rooms, etc	.80
Noncommissioned officers' rooms, etc	.60
Dining rooms, kitchens, etc	.50
Squad rooms, etc	.40
Wards, etc	.30
Halls, porches, furnace rooms, lavatories, etc	.25
Storerooms, basements, closets, etc	.15
Offices	.80
Stables (exclusive of stalls and lofts)	.25
Stables (stalls and lofts only)	.10
Shops (general and local)	.70
Warehouses, storehouses, etc	.20
Garages (storage)	.20
Other installations computed by application of comparable units above.	

h. Where unusual conditions exist, due to mounting height, types of fixtures, color of walls or ceilings, etc., and it is believed that installations calculated in accordance with the schedule shown above do not afford adequate illumination, The Quartermaster General will upon receipt of complete information authorize an installation to meet requirements.

363. Faults in illumination.—The faults most common in illumination of buildings may be stated as follows:

a. Improper fuses.—All safety is abandoned when a fuse of too great capacity is used. There are strict regulations requiring the use of fuses of the proper capacity.

b. Unclean lamps and shades.—Lamps and shades should be cleaned frequently because they soon become coated with a film of dust which may reduce the light by 10 or 15 percent. This is particularly true of inverted dome fixtures. When lamps become blackened with use they should be replaced.

c. Gas-filled lamps without shades or frosting.—The eyes are injured and the glare makes the remainder of the room seem unusually dark unless there are proper diffusing shades.

d. Large lamps in places not necessary.—These sometimes cause headaches and eye trouble. It is very important that the lamps in each room be suited to the particular illumination requirements.

364. Wiring.—It is desired to draw attention to the great importance of seeing that electric wiring of any kind is installed only by competent wiremen and in strict accordance with rules and requirements of the National Electric Code. Strict adherence to this custom will undoubtedly result in a large reduction, if not complete elimination, of troubles caused by—

a. Overloaded circuits.
b. Overloaded fuses.
c. Defective joints and splices.
d. Improper equipment.
e. Poor workmanship.
f. Poor illumination, etc.

CHAPTER 14

FIRE PROTECTION AND PREVENTION

365. General.—The science of fire protection may be considered under three divisions:

a. Causes which originate the fire.—These call for a thorough study of the hazards so that they may be eliminated or suitably safeguarded.

b. Structural features.—These should receive such consideration that those fires which cannot be prevented may be confined to the area in which they originate. This can be achieved to a large extent by the adoption of good construction, reasonable areas, and protection from exterior exposure.

c. Apparatus for fire extinguishment.—Where preventive measures fail and hazards have caused a fire, apparatus for extinguishment must be relied upon. The confidence with which any problem is approached is dependent in a great measure upon the probability

of its satisfactory solution, and such probability may be based on past performances along the same or similar lines. Definite and satisfactory results of the application of practical fire prevention are innumerable, and attention is drawn here to one of the most prominent conclusive examples. Upon the entry of the United States in the World War in 1917, the Construction Division of the United States Army was intrusted with the construction of 16 cantonments. Because of the need of utmost haste, these camps were of flimsy wooden construction, thereby creating fire hazards of the first magnitude. The fire preventive and protective features were delegated to engineers drafted from the National Board of Fire Underwriters. The results obtained were successful to an unprecedented degree, for when these cantonments were turned over to their commanding generals there had been a fire loss of less than $3,000 upon the $100,000,000 worth of construction; and during the period of occupancy, the per capita fire loss in these wooden cities averaged about one-fifth of that of civilian cities.

366. Standards for safeguarding hazards.—Standards for safeguarding existing hazards are in general well-established, and those for new hazards are formulated as promptly as practicable. At military posts, etc., frequent inspections are essential by the officer in charge of a qualified assistant to secure the protection from hazards in accordance with standard requirements and to maintain this protection once it has been established. The inspector in order to be successful must have the ability to recognize fire hazards where they exist, the practical knowledge of how to safeguard against them, a persistence in securing necessary corrections, the talent to observe and report accurately the conditions found, and, above all, tact and diplomacy in dealing with those who have authority to order unsatisfactory conditions corrected. The inspection of any structure involves consideration of its construction, hazards, and fire protective appliances. Each will be considered separately.

367. Inspection.—Upon approaching a property, the inspector should be in possession of its plans which should include its immediate surroundings. He should observe its general construction, outline, and general condition from the outside. Notes should be made of location, condition, and grade of nearby streets, distances to fire hydrants in the vicinity, and distance to the nearest fire station.

368. Exposure.—The loss due to fire communicated by exposure is about 16 percent of the total fire loss. Therefore, special attention must be given to adjoining buildings and materials stored therein.

369. Roofs.—The structural problems of the inspector have to do principally with existing buildings, although his advice should be and is frequently sought in connection with new structures. Each building should have a fireproof or fire-resisting roof covering. Wooden shingles are particularly receptive to sparks either from the chimney in the building or from adjacent buildings. Cornices and gutters should be of incombustible material. A scuttle should be provided with substantial steps or ladder leading thereto.

370. Tour of inspection.—The inspector, who should start his tour from the upper stories of a building, should observe that mortar joints in the brickwork are in good condition above the roof; he should observe, while in the attic, that the mortar joints are tight and that there are no cracks in the brickwork below the roof deck. If the integrity of a chimney is in doubt, a test for tightness should be made by making a smudge fire at the bottom and closing the top tightly after the smoke issues freely from the top. All smoke-pipe intakes to flues which are not in use should be securely closed.

371. Stairways; automatic doors.—All stairways (except in dwellings) and shafts containing elevators, hoistways, and ventilating ducts should be inclosed with brick, concrete, tile, or other suitable walls. Skylights should have metal frames and sash and be glazed with thin glass and protected from above by galvanized wire screens. If there are no inclosures and the vertical openings from floor to floor are protected by automatically closing fire or trap doors, observations should be made to see that these devices are in operative condition and that they are not likely to become obstructed.

372. Openings under buildings.—Buildings on posts or piers having no cellars should be tightly closed in down to the ground so as to prevent combustible debris from blowing in or being placed underneath. Openings provided for ventilation should be protected with fine screens. An opening should be provided for access beneath the building, but it should be kept closed. Fixed ladders to and on the roof should be inspected and kept in serviceable condition.

373. Care and maintenance of property.—*a.* The care and maintenance of property is a feature of fire prevention that can be understood by everyone. The inspector should impress upon the official in charge the importance of housekeeping and emphasize the necessity of so organizing his operating force that best results will be produced.

b. A system of daily or weekly inspections of the property should be established, and reports made out on forms to be signed by the delegated inspector and turned over to the officer in charge of the

activity. These reports should cover the following: work done by the cleaning force, specifying portions of buildings which have not been given proper attention; presence of any rubbish which may remain at the end of the day, or sweepings which should have been removed and disposed of in a safe manner; oily waste or rags not in suitable waste cans. Reports should note whether ashes are properly handled and removed (wooden receptacles should not be used); whether oils and other hazardous substances are handled in accordance with proper rules; whether packing material and surplus containers are carefully handled; and whether an unnecessarily excessive stock is kept on hand. "No smoking" signs should be in place. Safety matches should be used exclusively.

c. Where watchmen are employed, their records should be reviewed and the activity visited occasionally at night to see that the watchmen are functioning properly. Wherever possible the watchmen should accompany the inspector on his rounds, and watchmen should be encouraged in calling the inspector's attention to unsatisfactory conditions. If the inspector cannot inspect an activity frequently, provision should be made to have someone assigned from the local personnel to make inspections. Suitable inspection forms should be provided and executed and should be reviewed by the regular inspector.

374. Electrical installations.—*a. Precautions.*—All electric wiring and installations of electrical appliances, for permanent or temporary use, should be made to conform to the National Electric Code, as recommended by the National Board of Fire Underwriters. The following precautions are necessary:

(1) Alterations or extensions should be made only by authorized electricians.

(2) Electric irons, stoves, high candlepower lamps, etc., should not be installed on a circuit if by so doing the circuit would be overloaded.

(3) Paper shades should not be used on electric lights.

(4) No articles, noninflammable or otherwise, should be hung on electric wiring or on light globes in wall sockets.

(5) Ten to fifteen ampere fuses only should be used on lighting circuits, and at no time should fuse breaks be bridged by other than the proper fuses.

(6) Electric irons should not be used unless provided with pilot lights.

(7) Drop or extension cords should not be shortened by the tying of knots.

(8) Electric wiring should, under no conditions, be looped or otherwise hung on nails, pipes, or other metal objects.

(9) All extension cords used or attached to movable fixtures and appliances should be of the reinforced type.

(10) Telephone and signal wiring should not be installed in such manner that it will come in contact with electric wires.

(11) Where alterations or repairs are made in the electric wire circuits, all loose ends and dead wiring should be immediately removed upon the completion of such alterations or repairs.

b. Radio installations.—The necessary fire prevention methods to be employed in the installation of any radio transmitting or receiving set are as follows:

(1) No part of the antenna should be constructed in such manner as to permit it to cross over or below any wires charged with electricity.

(2) No energy from electric lines should be used by the installations, except for standard alternating-current sets and standard battery recharging sets or rectifiers.

(3) A single pole, double throw switch, with a carrying capacity of not less than 20 amperes, should be properly installed for grounding antenna when set is not in use.

(4) All wires leading to source of power supply should be well-insulated and of sufficient current-carrying capacity to avoid heating when set is in use.

375. Coal and wood stoves.—*a.* Stoves should be at least 18 inches from side walls and woodwork at all times. When stoves are placed closer than 3 feet to side walls or woodwork, an air space of 1 inch should be left between the walls or woodwork and the protecting sheet metal or asbestos, in such manner as to allow ventilation from bottom to top; the protective sheet metal or asbestos to extend at least to the top of stove.

b. Metal mats should be placed under all stoves, extending not less than 18 inches beyond the front and 6 inches on sides and back.

c. Kitchen ranges (coal) should be placed directly on brick or cement hearths provided such hearths are installed in the floors. Otherwise, the ranges should be elevated on uniform sized bricks covered with a metal mat.

d. Stoves may be set in convenient places, but long runs of pipe should be avoided. Stove pipes should be made spark tight; and where pipes pass through wood roof construction they should be guarded by galvanized iron ventilating collars, at least one and one-half times the diameter of the pipe, incasing smoke pipe so as to leave an air space of not less than 1 inch around it. Metal

thimbles, supported by metal collars holding pipes at least 6 inches from woodwork, should be used to conduct stove pipes through side walls when it is necessary to construct flues on outside brackets.

e. Bracket shelf supports for tile joint base galvanized chimneys, on sides of frame buildings, are hazardous and should be avoided when possible.

376. Gas stoves.—*a.* Gas stoves should be permanently connected to gas main and should be placed at least 7 inches from walls or woodwork.

b. The use of flexible tubing should be prohibited. Only iron pipe connections should be made to portable gas fixtures.

377. Kerosene stoves.—*a.* The use of kerosene stoves should be prohibited.

b. When the use of kerosene stoves is necessary, special precautions should be taken to guard against fire. They should be cleaned daily and wicks kept properly trimmed.

378. Gasoline stoves.—The use of gasoline stoves for cooking and heating purposes should be prohibited.

379. Other safeguards for ranges.—*a.* All large ranges, gas, coal, wood, or oil burning, subject to extensive use, should be provided with hoods, constructed of substantial metal and large enough to collect all greasy vapors. The hood should preferably be placed at least 9 inches below any wooden or other combustible ceiling. Ventilating pipes of a proper gage metal to permit their burning out without damage to the building, or building contents, should be connected to a suitable brick flue lined with burnt clay. The pipe should be sufficiently large to take care of all vapors or fumes. Horizontal ventilating pipes for ranges in kitchens should be avoided whenever possible.

b. All stoves should be free from cracks, have well-fitting doors, and be supported on legs.

380. Fireplaces.—*a.* Improperly built fireplaces are a decided fire menace. Thin walls, combustible material against their backs, combustible mantels, and unsafe hearths are common causes of fire.

b. Screen protection for fireplaces, to keep sparks from being thrown onto the floor and to prevent children from having their clothing ignited, should be provided for every fireplace that is used, even if only used occasionally.

381. Chimneys and flues, cleaning and inspection; reports.—*a.* All chimneys and flues used as outlets from furnaces, boilers, and flues from ventilating systems over ranges where cooking is done should be kept free and clear of soot, greases, and all foreign sub-

stances at all times. All flues and chimneys from furnaces where wood and soft coal are used should be cleaned yearly. All flues from ventilating systems over ranges where cooking is done should be cleaned semiannually. Reports of cleaning and inspections should be kept in the office of the fire marshal.

b. Ventilating thimbles for the protection of partitions, side walls, roofs, etc., where pipe passes through should be carefully inspected annually. Rust-eaten thimbles or collars permit fires to occur in concealed places, if they are not given proper attention.

c. Flues or chimneys built upon brackets, particularly if these are of wood, are exceedingly dangerous. This is so because such brackets are likely to settle and open cracks from which sparks can issue. Chimneys or flues should in all cases be built from the ground.

d. Defective flues constitute one of the most common causes of fire. A chimney is more or less racked by wind, which may result in cracks being opened, particularly in attics and at other points where these would not be readily noticed.

e. The height of all chimneys and flues of stoves used for domestic purposes or open fireplaces should be not less than 5 feet higher than the highest point of the roof of the building of which they are a part.

f. Tile chimneys and stacks should not be permitted inside any building.

g. In chimneys which are inclosed or form a part of the interior of any building, no joists or girders should rest or be supported on the walls of such chimneys. Framing around chimneys should be so constructed that in no case will any joists or timbers be placed nearer than 2 inches from the outside face of the walls, and the distance from the inside of any flue to any joists should not be less than 7 inches. In fireplaces, such joists or timbers should not be placed closer than 20 inches to the opening.

h. Unused chimney holes should be securely closed with tight-fitting stoppers.

382. Skylights; protection.—*a*. All skylights, except those glazed with wired glass, when inclined at an angle of over 45°, should be protected by wire screens of galvanized-steel wire cloth.

b. For all ventilating skylights, hinged, pivoted, or sliding sash, care must be taken that opening is thoroughly protected from flying brands or sparks.

c. All screens should be placed 6 inches or more above skylights to be protected and should project the same distance beyond edges.

d. Screens used for protecting side lights should be placed not less than 6 inches from lights or openings so protected.

e. Screens for vertical or saw-toothed skylights or sash, or those inclined at an angle of over 45°, should be turned in at the top and sides in such a manner as to exclude embers or sparks from space between the screens and glass.

383. Laundries.—*a*. Stoves, boilers, steam pipes, electric irons, steam presses, gas heaters, gas irons, flues, chimneys, and smokestacks should be safeguarded so as to protect woodwork, floors, partitions, walls, ceilings, and roofs.

b. Kerosene stoves should not be used for heating or for any other purpose.

c. Electrical installations should be inspected once each month by a competent electrician for the purpose of detecting overloaded circuits, bridged fuses, exposed wiring, exposed switches, looped wiring over nails or hooks, dust accumulation on open electric motors, and other misuse of equipment. Corrective measures should be taken immediately upon discovery of discrepancies.

d. Metal receptacles should be provided for the disposition of oily waste, rags, rubbish, etc., which should be emptied daily; this refuse to be burned under the boilers of the plant or taken to a prescribed dump or incinerator.

e. Ventilated lockers should be provided when necessary for the use of employees' oily work clothing.

f. Lubricating oils and other inflammable liquids should be kept in a regular place provided with drip pans made of metal. These liquids should not come in contact with woodwork.

g. Dust and lint should not be permitted to accumulate on rafters, skylights, floors, benches, beams, etc.

h. Clothing received for laundering should not be permitted to remain in piles longer than 24 hours.

i. Inspections should be made each day after closing hours for the purpose of detecting any irregularity which may cause a fire.

j. Gas fixtures should be permanently installed with pipe fittings and under no circumstances should flexible tubing be used.

k. Aisle space should not be obstructed after closing hours by trucks or any other objects.

l. Watchman should be maintained in and about laundries from closing time until the plant is opened for work. They should see that all steam pipes, gas cocks, and valves are closed, and that electric power switches or main switches are opened. Proper written instructions should be issued to each watchman on duty.

m. Fire-alarm facilities should be sufficient to bring about a prompt response of all available fire-extinguishing apparatus in case of fire.

n. No temporary building or shed should be permitted closer than 50 feet to main buildings or dry-cleaning plants.

o. Employees should be drilled and instructed in the use of fire equipment at least once a month and should be made familiar with the operation of all fire appliances at their disposal.

p. Fire appliances should be installed in accordance with the methods and allowances prescribed.

384. Dry-cleaning plants.—*a.* Dry-cleaning plants should be located a distance of not less than 50 feet from any other building.

b. Gasoline should not be stored in drums for daily use but kept in underground tanks.

c. Empty drums should be properly drained and stored. .

d. Light and power control switches should be located on the outside of the building unless switches operating in oil are installed.

e. Electric motors, if used for operating dry tumblers, should be partitioned off from the main dry-cleaning room.

f. Floor ventilators should be provided, at least 6 inches high around all outside walls, with proper ventilation facilities overhead.

g. Where steam is available, a steam-pipe system should be installed for fire protection, with a quick lever-control valve located in a safe place for immediate operation.

h. Smoking should not be permitted in the plant or within 50 feet from the outside of building; signs to this effect should be posted and rigidly enforced.

i. Keyless sockets should be provided for all lights within the building and wire guards installed on all light globes.

j. Heating should be only by steam or hot water furnished from a a detached heating plant.

385. Garages.—*a.* The inherent hazard of gasoline is largely responsible for fire losses of public and private garages. Methods by which destructive fires have been ignited include matches, forges, furnaces, torches, heaters, backfiring, static electricity, electric arcs (including breaking of incandescent lamps, gas-burning devices, spark ignition system on cars, spontaneous ignition of oily waste, etc.

b. Refuse and oily rags used for cleaning automobiles should be properly disposed of after use.

c. Cans with covers should be maintained, installed for disposition of oily rags, waste, etc., in all repair shops and garages. Cans should be emptied daily.

d. Heating apparatus using coal, wood, or other open flame-producing fuel should not be installed in garages or automobile repair shops.

386. Miscellaneous hazards.—The commonly found miscellaneous hazards are mainly process hazards found in the industries. Regulations have been prepared to safeguard the more common, and for the more infrequent the inspector must depend upon his judgment.

387. Power hazards.—The power hazards include steam boilers and engines, electric motors, internal-combustion engines, coal-gas producers, fuel oil, and refrigeration, which should be safeguarded in accordance with the National Electrical Code and regulations governing furnaces, steam pipes, gas piping, inflammable liquids, and refrigeration, respectively.

388. Storage hazards.—*a.* The hazards incident to the storage, handling, and use of chemicals, paints, and oils are similar in character. Some chemicals possess inherent hazards, while others are hazardous only when in contact with substances with which they readily combine. It is important, therefore, that where chemicals are present, their nature is ascertained and the manner of storage and method of use are investigated.

b. Strong acids should be stored outside, nitric acid being especially dangerous. Lime, if moderately moistened with water, will generate sufficient heat to ignite combustible material with which it is in contact. Calcium carbide, if moistened, generates acetylene gas, and should be stored in watertight containers. Nitrocellulose products, of which motion-picture films are the most common, are highly inflammable. Films should be stored in accordance with the regulations governing them.

389. Inflammable volatiles—kerosene, gasoline, etc.—Inflammable volatiles include kerosene, alcohol, benzol, ether, gasoline, and turpentine. Their relative hazards are determined by their flash point. The handling and storage of these substances should be in accordance with regulations governing containers for hazardous liquids. Gasoline when used in buildings should be kept in approved safety cans. It should be stored outside but never on a window ledge or fire escape. It should never be used where there are open flames.

390. Paints.—The hazard of paints is due to possible spontaneous ignition, caused by carelessness in not removing and destroying rags, sawdust, etc., which may have become impregnated. Painters' clothing should be kept in well-ventilated metal lockers, not located where paint stocks are stored.

391. Dust.—The dust from almost any flammable substances and from some metals which are readily oxidizable is explosive and may be ignited by a flame or spark. Such explosions may be prevented by eliminating the dust entirely through adequate dust-collecting systems or by prohibiting open flames or other possible sources of ignition.

392. Spontaneous ignition.—*a.* "Spontaneous combustion" is a misnomer. Ignition, rather than combustion, is the phenomenon which is spontaneous. The proper expression, therefore, is not spontaneous combustion but spontaneous ignition. It is a frequent though little understood fire cause, and with a better understanding of its principles and necessary simple precautions the danger may largely be eliminated. Spontaneous ignition may be defined as ignition caused by the internal development of heat. All combustion is a process of rapid oxidation, that is, the energetic combining of oxygen with the substance burned. Combustion always involves oxidation, but oxidation may take place without combustion. In slow oxidation, under ordinary conditions, heat is produced so slowly that it escapes before there is any appreciable rise in temperature. Under other conditions in material subject to oxidation, so subdivided as to present a maximum surface and at the same time so protected as to prevent the escape of heat, the temperature rises and oxidation, like all chemical action, proceeds faster. This, in turn, further raises the temperature until the point of ignition is eventually reached. This is spontaneous ignition.

b. In general, spontaneous ignition may be possible in all classes of substances that will burn, but usually it occurs because of some special favorable condition or quality. Eliminating certain chemicals and explosives, which need not be considered here because their peculiar hazards are well-recognized, three conditions are always necessary. One is that air must be present; the second is that the material must be finely divided so as to present a relatively large surface subject to oxidation; the third is that the material must be so placed that heat generated by oxidation cannot readily escape. A large pile of finely divided material such as coal satisfies all three of these conditions. The interstices are so small that they do not permit sufficient circulation of air to cool the mass effectually, while they do permit the ingress of sufficient air to support oxidation. Coal should not be piled over 12 feet deep nor in such a manner that any point in the pile will be over 10 feet from the outside surface. It should be placed in layers not over 2 feet thick in building up a coal pile. If possible, only screened coal should be stored. Unscreened coal should be stored so that the coarse and fine coal are

evenly mixed. Moisture is also a factor in spontaneous ignition, being a necessary condition in many cases.

c. The so-called "unsaturated" vegetable oils, notably linseed oil, are especially likely to spontaneous ignition because of their property of absorbing oxygen in drying. This drying, which is the property which makes linseed oil valuable in paints, is not a process of evaporation but is an absorption of oxygen due to a natural affinity for it. Such oxidation forms a new and different chemical compound, involving an increase in weight. Linseed oil will not heat appreciably when in bulk because there is not sufficient surface for oxidation, but when distributed over bunched rags conditions exist for the familiar "spontaneous ignition of oily rags."

d. No vegetable oil will cause spontaneous ignition unless it has the property of drying by means of absorbing oxygen, and no animal oil will cause spontaneous ignition unless it has the property of becoming rancid or taking up oxygen. The danger of causing fire is directly proportionate to the degree that an oil may have either one or the other of these properties.

e. At ordinary temperatures, mineral oils in their liquid state have no affinity for oxygen and are therefore less hazardous than vegetable oils.

f. Mixtures and impure substances are usually more dangerous than the same substances in their pure state.

393. Precautions against spontaneous ignition.—It is obvious that the prevention of fire in many instances, some of which are listed below, requires constant and careful supervision.

a. Observe conditions of storage and use.

b. Safeguard the storage of raw materials which in combination with others will cause chemical action.

c. Exercise the utmost care in giving proper attention to stocks which are hazardous in themselves.

d. Oily mops should be kept in the open, subject to free circulation of air. Suitable racks should be constructed so as to hold mops with the handles down.

e. Ventilation should be provided in every known case where spontaneous ignition is likely to occur.

f. Substances subject to spontaneous ignition in storage should be carefully inspected at regular intervals, and every precaution taken to insure against allowing conditions to favor spontaneous ignition.

g. Cleanliness and good housekeeping are important factors in eliminating the dangers of spontaneous ignition.

WAR DEPARTMENT
Q. M. C. Form No. 90
Revised Oct. 23, 1937

At Fort Hamilton. Date March 30, 1939

1. Post generating plant, acti Date completed April, 1910
Date completed Phase Single & 3 Number of conductors 2 &3
2. If purchased, give name an Power Prim.4056-3-p Light 125
mber of poles 124 Kind of poles wood
3. Incoming lines at reservati sulators 2500-glass Manholes -
Frequency 60 Insulators Glass
Length of line from co Duct lines
4. Service lines from reservat Pellet Manufacturer General Electric
Length, in miles e 21 Aggregate K. V. A. 322½
Number of: Poles orms and brackets. und
Kind of: Poles tral #6 copper wire from neutral to gro
5. Substation: Original cost 00 Date completed April , 1910
Type of construction [illegible]e or amperage 6.6
Main transformer ban e or lumens 100
Quantity Length of system 9769 feet
Name-plate data How mounted On iron poles.
nected 176.865
Mounted outdoor or in Number installed -
Lightning arresters: - Number installed -
Name-plate data Pe - Number installed -
Where and how mount Number of D. C. installed -
Switchboard: Material 69-13/24 Number installed 41
Number of panels 5 - Number installed -
List of instruments tus, giving group designations, total quantities, and
meter watt hr.; rs - 2.6 KW; miscellaneous kitchen
1-time switch; rators - 9.4KW;2 gas pumps-.49KW; *
Number of circuits le onnected (estimated) 250
Voltage regulators: Q t desk and bracket fans on reverse side of this sheet.
Name-plate data spital equip.-33.1KW;1 hot plate-1.5KW
16 clocks - .64 KW
DATE

Street-lighting regula
Name-plate data Pr

Other Government-ow

Apparatus owned by
test switch; 1-

INSTRUCTIONS.—This form i y reported to the Quartermaster General, giving all particulars
and turned over for use. t necessary to submit new forms when reporting such slight modi-
Forms will be prepared in tripl the electric system in operation, entries hereon will be checked
forwarded to the Department or Co Entries hereon will be considered accurate at all times.
eral. At independent stations, form
forwarded to the Quartermaster Gen
U. S. GOVERNMENT PRINTING OFFICE 3—9643

245260°—40 (Face p.

8—0643

LED DING ER	BELTED OR DIRECT CONNECTED	AVERAGE HOURS OPERATED PER MONTH	WORK PERFORMED
2	Direct	* 150	Operates Blower
5	"	16 yr.	Operates Elevator
5	"	16 yr	Operates Conveyor
0	"	30	Operates Pump
3	"	* 150	Forced Draft Blower
2	"	* 150	Operates Blower
5-S	"	* 150	Forced Draft Blower
2	Belted	60	Air Compressor
3	Direct	* 30	Water Circulator
5	"	30	Water Circulator
3	"	112	Ventilator
3	"	* 150	Operates Blower
9	"	* 150	Forced Draft Blower
5	"	* 150	Forced Draft Blower
3	"	144	Pump Injection
3	"	180	Refrigeration Unit
3	"	360	Ventilation
7-S	"	* 150	Forced Draft Blower
7-N	"	* 150	Forced Draft Blower
8	"	* 150	Operates Blower
3-S	"	* 150	Forced Draft Blower
3-N	"	* 150	Forced Draft Blower
5	Belted	20	Operates Lathe
7-D	Direct	* 150	Forced Draft Blower
9	"	$6\frac{1}{4}$	Dough Mixers
9	"	$1\frac{1}{2}$	Dough Moulder
9	"	$4\frac{1}{2}$	Bakery Outfit
9	"	* 150	Forced Draft Blower
9	"	* 150	Forced Draft Blower
9	"	* .30	Circulating Pump
1	"	1/2	Operates Sump Pump
1	"	* 150	Operates Blower
1	"	* 30	Operates Circulating Pump
1	"	* 30	Circulating Pump
1	"	1/3	Fire Siren
5	"	* 150	Forced Draft Blower
5-B	"	* 150	Operates Blower
55	Belted	40	Operates Drill Press
59	"	60	Operates Circular Saw
73	Direct	60	Cooling Unit
73	"	* 150	Forced Draft Blower
		* Operated	during heating season.

WAR DEPARTMENT
M. C. Form No. 91 (Old 424)
Revised Dec. 3, 1920

At Moffett Field, Ca February 28, 1936.

NUMBER	CAPACITY	MA	REMARKS
4974675	75 KVA	Gen. Ele	Hangar Vault #1 Lighting
4974684	75 KVA	"	" " " Power
4974695	75 KVA	"	" " " "
4974696	75 KVA	"	" " " "
4974679	75 KVA	"	" " #2 Lighting
4974677	50 KVA	"	" " " Power
4974678	50 KVA	"	" " " "
4974676	50 KVA	"	" " " "
4974674	75 KVA	"	" " #3 Lighting
4974687	75 KVA	"	" " " Power
4974691	75 KVA	"	" " " "
4974686	75 KVA	"	" " " "
4974680	75 KVA	"	" " #4 Lighting
4974690	75 KVA	"	" " " Power
4974688	75 KVA	"	" " " "
4974683	75 KVA	"	" " " "
4974681	75 KVA	"	" " #5 Lighting
4974693	75 KVA	"	" " " Power
4974692	75 KVA	"	" " " "
4974685	75 KVA	"	" " " "
4974673	75 KVA	"	" " #6 Lighting
4974694	75 KVA	"	" " " Power
4974682	75 KVA	"	" " " "
4974689	75 KVA	"	" " " "
2039611	7.5 KW	West'h'e	" " #6 Field Lighting
2039249	3. KW	"	" " " " "
2039250	3. KW	"	" " " " "
4444134	20 KW	Gen.Elec	Helium Plant Vault St. Lighting
4454685	15 KW	" "	" " " " "
4974597	25 KVA	Gen. Ele	" " " Power
4974593	25 KVA	"	" " " "
4974596	25 KVA	"	" " " "
5050370	25 KVA	"	" " " Lighting
1514842	25 KVA	Allis Ch	South Circle Lights & Power
1514841	25 KVA	"	" " " " "
1514844	25 KVA	"	" " " " "
1514840	25 KVA	"	North " " " "
1514839	25 KVA	"	" " " " "
1514843	25 KVA	"	" " " " "
1756355	25 KVA	Westing	Barracks Vault Lighting
1756358	25 KVA	"	" " "
1519115	10 KVA	Allis Ch	North Neon Sign Lighting
1519116	10 KVA	"	South " " "
No Numb	1.5 KW	Diamond	Well A Pump House Lights & Controls
1518205	15 KVA	Allis Ch	South Flood Light Tower Lighting
1518206	15 KVA	"	" " " " "
1514710	15 KVA	"	M.H.#7 Gas. Pumping Sta. Power
792-1	37.5 KVA	Penns. T	M H.#11 Motor Test Bldg. Power

DATA SHEET FOR TRANSFORMERS

number and capacity of transformers; for exam-

urer.
the next five columns.
e.
"Good," "Serviceable," or "Unserviceable."
ansformer, the total costs should be given.
which should be noted, like a high or low volt-

led out for permanent record. When this shall
ained at the post or station; the other two (2)
partment Headquarters, one copy to be retained
he Quartermaster General.
ations, alterations, and additions will be reported
n of the work.

T PRINTING OFFICE: 1929 3—9642

WAR DEPARTMENT
. M. C. Form No. 92 (Old No. 426)
Revised June 12, 1925

At Fort George Wrighłrch 12, 1938.

Post Number	DESIGNATION	WATT-HOUR METERS. Name of Manufacturer	2 or 3 wire	Date Installed	Date Last Calibrated
2	ɪield Officers (	inghouse	2	1906	1929
2	" "	inghouse	3	1929	1929
3	" "	"	2	1904	1926
3	" "	"	3	1929	1929
8 A	Double Officers	"	2	1906	1929
8 A	" "	"	3	1929	1929
8 B	" "	"	3	1899	1926
8 B	" "	"	3	1929	1929
9 A	" "	ompson	3	1904	1926
9 A	" "	inghouse	3	1929	1929
9 B	" "	ompson	3	1904	1926
9 B	" "	inhouse	3	1929	1929
11 A	" "	ompson	3	1899	1926
11 A	" "	inghouse	3	1929	1929
11 B	" "	ompson	3	1899	1926
11 B	" "	inghouse	3	1929	1929
13 A	" "	"	3	1929	1929
13 Am	" "	"	3	1929	1929
13 B	" "	ompson	3	1899	1926
13 B	" "	inghouse	3	1929	1929
15 A	" "	Electric	3	1932	1932
15 A	" "	inghouse	3	1929	1929
15 B	" "	hompson	3	1899	1926
15 B	" "	inghouse	3	1929	1929
16 A	" "	ompson	3	1906	1926
16 A	" "	inghouse	3	1929	1929
16 B	" "	ompson	3	1906	1926
16 B	" "	inghouse	3	1929	1929
17 A	" "	ompson	3	1899	1926
17 A	" "	inghouse	3	1929	1929
17 B	" "	ompson	3	1899	1928
17 B	" "	inghouse	3	1929	1929
20 A	Batchelors Offic	"	2	1929	1929
20 A	" "	"	3	1929	1929
20 B	" "	"	3	1906	1928
20 B	" "	"	3	1929	1929
20 C	" "	Electric	2	1929	1929
20 C	" "	inghouse	3	1929	1929
20 D	" "	"	2	1906	1928
20 D	" "	"	3	1929	1929
20 E	" "	"	2	1906	1928
20 E	" "	"	3	1929	1929
20 F	" "	"	2	1906	1926
20 F	" "	"	3	1929	1929

.TT-HOUR METERS

3—9641 Date March 17, 1938.

TALLED			WATT-HOUR METERS				
...ts	300 watts	Other wattages	Type or Style	Name of Manufacturer	2 or 3 wire	Date Installed	Date Last Calibrated
			AC	Thompson	3	1898	1928
			"	Westinghouse	2	1898	1928
			"	"	3	1906	1926
			"	"	3	1906	1928
			"	"	2	1930	1930
			"	Thompson	3	1899	1928
			"	"	3	1899	1928
			"	Gen. Elect.	3	1929	1929
			"	Westinghouse	3	1906	1926
			"	Thompson	3	1903	1926
			"	"	3	1903	1926
			"	Gen. Elect.	3	1932	1932
			"	Westinghouse	3	1929	1929
			"	Gen. Elect.	3	1934	1934
	4		"	" "	3	1928	1928
			"	" "	3	1935	1935
			"	Westinghouse	3	1934	1934
			"	"	3	1934	1934
			"	"	3	1934	1934
			"	"	3	1933	1933
			"	"	3	1933	1933
			"	"	3	1933	1933
			"	"	3	1933	1933
			"	"	3	1933	1933
			"	"	3	19 33	1933
			"	Thompson	2	1899	1926
			"	Westinghouse	3	1929	1929
			"	Thompson "	2	1899	1926
			"	Westinghouse	3	1929	1929
			"	Thompson	2	1899	1926
			"	Westinghouse	3	1929	1929
			"	Thompson	2	1899	1926
			"	Westinghouse	3	1929	1929
			"	"	3	1931	1931
		3600 motors					

-ght modifications, alterations, or additions will be promptly reported to the Quarte General, giving the post number and designation of buildings concerned, with not be made which would affect lighting allowances. It is not necessary to submit ne when reporting such slight modifications, etc. Inasmuch as these forms are used and determine lighting allowances, data pertaining to authorized outlets and lam checked annually, or oftener if necessary, and reported for correction. Entries here considered accurate at all times.

QMC Form No. 98 combine[illegible]
WAR DEPAR[illegible]
(Revised Oct. [illegible]

At Mitchel Field, [illegible] February 29, 1940.

1. Source of water supply [illegible] 30-lbs. near Bldg. No. 19
2. Sanitary conditions surr[illegible] 30-lbs. near Bldg. No. 301
[illegible] 30-lbs.
3. Consumption—gallons [illegible]re 25-lbs. in Bldg. No. 301

	[illegible]ar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
4. Population supplied a.	[illegible]8	58	59	61	61	62	61	59	58	57
b.	[illegible]	58	59	59	59	60	59	59	56	57
c.	[illegible]3	58	59	60	60	61	60	59	57	57

5. Animals supplied—daily [illegible] (1,000 gal.) .0229

15. Description of source o[illegible]

Source of wat[illegible]

Water is not [illegible]

The water whi[illegible]e and thence to the Post
by gravity. The w[illegible]o feeder lines supplying
water to lavatorie[illegible]

16. Description of pump o[illegible]float switch on top of water
stand pipe. The s[illegible]ut out" when 6" from the top.
Any three of these[illegible]tions, and in case of emergen-
cy, all four can b[illegible]. The 1 deep well at No. Bell-
more is equipped w[illegible] trolled by a pressure

Well No.—	[illegible]	[illegible]	[illegible]	[illegible]
Total depth—feet	ressure, "cut out" at 40-lbs.			
Size of casing and material	ontrolled manually, if desired.			
Length of screen and mate[illegible]	normal conditions, pump sup-			
Size of screen openings	working day, and is in opera-			
Standing water level—feet				
Capacity—g. p. m.				
Drawdown—feet				
When drilled (Recondit[illegible]				
Cost				
How pumped				
Where is log available?				
Name of manufacturer				
Type				
Capacity—g. p. m.				
Head—feet				
Driving unit				
H. P. of driver				
Speed	September 1, 1938.			
Depth of setting—feet	rial No. A-3385, with G.E.			
Electric current Voltage	ost of pit housing pump			
Phase				
Cycles				
Date installed				
Cost				

3—10794

245260°—40 (Fa[illegible]

OMPRESSORS

No. 1	No. 2	No. 3	No. 4
	N O N E		

23. WATER ANALYSIS—P. P. M.

	Raw	Delivered
Total hardness as $CaCo_3$	10.0	10.0
Alkalinity (M. O.)	15.6	15.6
pH value	7.4	7.4
Total iron	0.0	0.0
Magnesium	3.7	3.7
Calcium	3.68	3.68
Sulphates as SO_4	2.05	2.05
Chlorides as Cl	4.8	4.8
Average color	0	0
Average turbidity	0	0
Date of analysis	12-17-34	
Where was sample taken	Faucet in Barracks	
By whom made	E.V.Freeman, Capt.QM	

INES, HEATERS, ETC.

Water Heating Boilers	Steam Boilers	Galv. Steel Storage Tanks	Galv. W. I. Storage Tanks	Nonferrous Storage Tanks
o action	No action	No action	--	--
orrosive	Corrosive	Corrosive	--	--

27. AMMONIATORS

Unit—	No. 1	No. 2
Name of manufacturer		
Type		
Capacity—maximum lbs.		
Water treated	N	O N E
Installed in Bldg. No.		
Date installed		
Cost		

28. CHEMICAL TREATMENT

Chemical	Average G. P. G.	Average P. P. M.
Alum		
Lime		
Chlorine		
Soda ash	N	O N E

MICAL FEEDING EQUIPMENT

No. 3	No. 4
E	

30. SOLUTION FEEDERS

Unit—	No. 1	No. 2	No. 3
Name of manufacturer			
Installed in Bldg No.			
Chemical used			
Dimensions of tanks		N O N E	
Number of tanks			
Date installed			
Cost			

tive" - analysis made by H.R. Livesay, Lt.-Col. M.C.

		CLEAR WATER WELL
Number of units		
Dimensions		
Material		
Capacity—gal		
Date constructed		
Q. M. G. Plan No.		
Cost		

Description of backwash equ

Maximum capacity of plant

Describe operation of plant

At

TER MAINS No. B'mre.

	6"	8"	10"	1"		
	I.	C.I.	C.I.	Copper	Tub.	
Building No.	71	12849	1916	40'		
Dimensions	A"	"A"	"A"	"K"		
Material	te	and Lead		1-pc.		
Capacity—gal	4"	4"	4"	4'		
Elevation of high water				7-20-39		
Elevation of grade	ost	375,000.00		15.00		
Height of tower						

Date constructed — n and where available:

Q. M. G. Plan No. — .G. Plan No. 6201-100

Cost — master (Utilities Division)

36. AUTOMATIC TION SYSTEMS

Installed in Bldg. No.		
Type		
Number dry pipe valves		
Number alarm valves		
Number sprinkler heads		
Booster pump—g. p. m.		
Storage tank—capacity		
Date installed	5	
O. Q. M. G. Plan No.	6	
Cost	I	

38. Miscellaneous Remar S SPACE FOR USE OF O. Q. M. G.

	ED	DATE
Drawing No. SB 2		
in Office of Bas		

3—10724

245260°—40 (Face

State condition of pumps, whether adequate in size and number, and furnish any other perti-
marks not covered in the form.

Under "Starting pressure," give the maximum pressure in air line to well just before water flow; under "Operating pressure," give average pressure in air line to well, with water flow- ler "Depth of setting," give distance from surface of ground to water inlet; under "Diameter :ion pipe," give diameter of water discharge pipe.

Give name-plate data and other information listed.

Furnish information as listed.

State whether water is corrosive, scale forming, or other action.

Under "Type," state whether up-flow or down-flow; under "Capacity," state maximum output ns per minute; under "Type of zeolite," state whether green sand or synthetic, and if synthetic, de name; under "Cubic feet of zeolite," give number of cubic feet in each tank; under "Exchange ," give number of kilograins (1 kilograin=1,000 grains) of hardness removed per regeneration; Automatic or manual control," state how control valves are operated.

Under "Type," state whether solution or direct feed for gas chlorine, or if using a solution of rite, so state and describe briefly under 31, giving name of equipment and method of operation; Capacity," give maximum capacity in 24 hours; under "Water treated," state whether raw, well, etc.

Under "Type," state whether direct or solution feed; under "Capacity," and "Water treated,"

Give average dosage for period of 1 year in grains per gallon or parts per million. Add other s not listed.

Under "Capacity," give maximum and minimum pounds per hour.

Furnish information as listed.

Furnish additional information, describing equipment under headings 25 to 30, stating condition, y, catalog references, method of operation, and any other pertinent remarks.

Under "Material," state whether wood, concrete, steel; under "Capacity," give total gallons each l contain for mixing chamber, sedimentation basins, and clear-water well; for capacity of filters, r output in gallons per 24 hours; under "Backwash equipment," state whether tank, pumps, or pump, giving pump capacity in gallons per minute and tank capacity in total gallons; under m capacity," give total water, in million gallons per 24-hour day, that can be put through plant; Description of plant operation," describe flow of water from source of supply through pumps or ty, and other units of the plant, such as aerators, mixing chambers, basins, filters, clear well, final discharge to post. State various steps in the purification process and points at which the ve chemicals are added.

Under "Material," state whether wood, concrete, steel, etc.; under "Capacity," give total gallons led; under "Elevation of high water and grade," refer these elevations to post datum; under of tower," give distance from foundation to bottom of tank.

Describe briefly, giving type of dam, approximate area of reservoir in acres, capacity of reser- n full, source of water, etc.

Under "Material," state whether cast iron, steel, concrete, wood stave, etc.; under "Class," if n, A. W. W. A. standard, state whether A, B, C, or D. If Federal specification cast-iron pipe, ether Class 150 or 250; if other type of pipe, give pressure rating; under "Cover," give average above top of pipe; state where layout plan is available showing length, size, and location of ocation of valves, storage tanks, and other components of the distribution system.

Under "Type," state whether wet pipe, dry pipe, or deluge; under "Booster pumps," if same are , give capacity in gallons per minute; under "Storage tanks," if same are installed, give capac- allons; under "O. Q. M. G. Plan No.," furnish number of plan or plans showing sprinkler system urtenances, such as booster pumps, storage tanks, etc.

Describe any fixed sprinkler system used for irrigation, stating source of water, size of pumps, led, area of post served, length and size of mains, number, size, and make of sprinkler heads, of operation, and any other pertinent details.

Furnish any other remarks on equipment under headings 32 to 37, such as adequacy of equip- ndition of structures, whether storage tanks are covered, etc.

This space is reserved for use of the O. Q. M. G. and is not to be filled in by authorities in the

QMC Form No. 94
WAR DEPARTMENT
(Revised Oct. 23, 1937)

AT Fort Monroe, Virg ATE September 30, 1938

1. Population served	(a)	rate
	(b)	
	(c)	
2. Water consumption	(a)	
	(b)	Plant by gravity.
	(c)	nt plant
3. Sewage flow	(a)	
	(b)	
	(c)	

WATER

Diameter	4"	0"	6"	8"	12"		
Material	TC	I	CI	CI	CI		
Length	500'	00'	3190'	200'	3000'		
Joint material	Cement	ad	Lead	Lead	Lead		
Average depth	5'	'	3'	3'	3'		
Date installed	-		1934	1934	1934		
Cost	-						

Number of manholes 104 Average depth $3\frac{1}{2}$'

Manhole elevations shown on Dra -

Sewer layout shown on Drawing 18 Post Map

Brief description of sanitary sewe ng pumping stations:

Gravity systems to ma

to sewage disposal pl

NAGE PUMPS

Pump No. —	1	3	4	5	6
Installed—Bldg. No.	92				
Name of manufacturer	Morri				
Type	Horiz				
Capacity—g. p. m.	1400				
Total head—feet	-				
Speed—r. p. m.	450				
Suction lift	21' 1				
Discharge head	12 lb				
Direct or belt drive	Dire				
Driving unit	Elec.				
H. P. of driver	25				
Automatic or manual start	Manual				
Unit Serial No.	Size				
Date installed	1921				
Cost	Est. $350				

7 11 39

UNIT—	SCRE	FILTERS	SLUDGE BEDS
Number of units	Non	Filter bed	(1) double
Dimensions		00'x 200'	2 compartments
Capacity		-	20' x 20'
Drawing Nos.		6174-232	6174 - 232 - 233
Date installed			9/30/37
Cost			

3—10723

TIC TANKS			15. CHLORINATORS			
	185		Installed—Bldg No.	12		
	12' x 6'		Name of mfr.	Wallace -	Tiernan	
	Brick		Type	M.D.P.-	D294	
	500		Capacity	100 lbs	(24 hrs)	
	185		Chlorine added to	sewage		
	Sub-soil		Average dosage	40 lbs	(24 hrs)	
	1933		Date installed	9/30/37		
	$ -	$	Cost	$ 860.	$	$

18. OTHER MEANS OF WASTE DISPOSAL

anure, method of garbage collection, etc.: Dry trash is gathered up by Police
ontract is let for the collection of garbage from organizations.
. Manure is taken from stables and placed in covered concrete
posed into fertilizer whichis later used on Post. In the event
contract to outside party is made to remove surplus manure

19. THIS SPACE FOR USE OF O. Q. M. G.	
Checked	Date

1. Same as 10.
2. Under capacity for screen chamber, sewage tanks, chlorinating chamber, and dosing chamber, otal capacity in gallons when full; for siphon and filter, give capacity in gallons per minute; udge bed, give capacity in cubic feet of sludge storage.
3. Under type, state whether vertical, centrifugal, or pneumatic; under capacity and head, give plate data; give sump capacity in gallons when filled.
4. Give dimensions in feet; under materials, state whether concrete, wood, steel, etc.; give capacity lons when filled; give building numbers served by tanks; give point of discharge, such as a stream, ground tile, etc.
5. Under type, state whether direct or solution feed; give capacity in pounds per 24 hours; state at which chlorine is added; give average dosage of chlorine in parts per million.
6. State condition of equipment, whether adequate and functioning properly, and other pertinent ks not covered by form.
7. Under name of builder, give contractor's name; under type, state whether natural or forced give stack height and diameter in feet; under capacity, state rate in tons per 8 hours; under can equipment, answer "Yes" or "No."
8. Describe briefly any dumps, sale of manure or garbage, composting of manure, method of garand trash collections, and any other details dealing with waste disposal not covered by the form.
9. This space is reserved for use of the O. Q. M. G. and is not to be filled in by authorities in the

WAR DEPARTMENT
Q. M. C. Form [illegible]
(Revised July [illegible])

Date of Report Dec. 22, 193[illegible]
(To be forwarded so as to reach O. Q. M. G

4

Station Fort Benning, Ga.

Line No.	PROJECT No.	PROJECT Designation	Cost F. Y. (include under projects major repair work listed on [illegible] of sheet)		WORK ACCOMPLISHED Unit	Operation—or $1,000 and Under Repairs No. of Units	Unit Cost
1							
2							
3							
4							
5							
6			145	00			
7	35	Electricity	140	00			
8			145	00			
9			145	00			
10			3852	22			
11	74	Coal	3900	00			
12			3900	00			
13			3900	00			
14			857	88			
15	63	Unloading Coal	500	00			
16			700	00			
17			700	00			
18			[illegible]2330	62			
19	2	Coal	[illegible]0000	00			
20			[illegible]0000	00			
21			[illegible]0000	00			
22			4360	60			
23	2	Wood	4425	00			
24			4425	00			
25			4425	00			
26			[illegible]6490	33			
27	2	Electricity (Cooking)	[illegible]5000	00			
28			[illegible]6000	00			
29			[illegible]6000	00			
30			[illegible]4068	59			
31	2	Gas	[illegible]7230	00			
32			[illegible]5000	00			
33			[illegible]5000	00			
34			510	32			
35	2	Gasoline	500	00			
36			500	00			
37			500	00			
38			[illegible]7760	46			
39	2	Total of Proje[illegible]	[illegible]7155	00			
40			[illegible]5925	00			
41			[illegible]5925	00			
42			[illegible]1139	53			
43	6	Electicity (Light & power)	[illegible]1000	00			
44			[illegible]6000	00			
			[illegible]6000	00			

[illegible] should include P. W. A., W. P. A. or other emergency activities.

Total population 13919
Mil. population 8274
Avge. no. animals 838
No. hosp. beds 344

[illegible] R. Alfonte, Lt., Col. [illegible], Quartermaster.
[illegible]a L. Singleton, (Commanding General). (Commanding Officer).
[illegible]ig. Gen., U.S.A.

3—6003
245260°—40 (Face p. 222)

HAT HAS BEEN OR IS TO BE ACCOMPLISHED (See AR 30-1425 and AR 30-1760)

3-8003

S	F. Y. 1939	F. Y. 1940	F. Y. 1941	F. Y. 1942
Large number of in- is Fort compel the emporary storage of e structure with for this purpose for t has a dirt floor, torage, is liable to d for future con- sts and plans have nd larger building nce it seems there cture for many years, e, re-erect it at a nd rearrange it to can be done for ap- requested.				15,000.00
s have been made dur- tilities shops, but ed. This is partic- rpenter shop, and blacksmith shop, where an 16 years of con- $8,000.00 would re- e costs.				8,000.00
any improvements have years, but demands lacking for cold ust be refrigerated. oad and it is evident ed. The building ncrease in equipment. remodelled, and rein- circulatory system completed, but the				30,000.00
area along Gaines anent NCO quarters grading and incom- foundations and rading and about tion of storm water proximately				9,500.00
main sanitary sewer st proper, and dump-				30,000.00

WAR DEPARTMENT
Q. M. C. Form 95
(Revised July 19, 1939)

Date of Report
(To be forwarded so as to reach O. Q. M. G. …

Station Fort Benning, Ga.

Line No.	PROJECT No.	Designation	…l Cost F. Y. (…clude under re… …jects major re… …work listed on …rse of sheet)		WORK ACCOMPLISHED Unit	Operation—or $1,000 and under Repairs No. of Units	Unit Cost	
1			6747	75				
2			7700	00				
3	9	Gas	7700	00				
4		)Power)	7700	00				
5			2249	25				
6			2500	00				
7	9	Electricity	2500	00				
8			2500	00				
9			101380	40	Emp	38-Civ	31-Enl.	
10			104155	48		43- "	31- "	
11	1	Salaries	110835	48		43- "	31- "	
12			110835	48		43- "	31- "	
13			230	36				
14			230	00				
15	3	Operating Suppli…	230	00				
16		Lub. Oils	230	00				
17			18	20				
18			19	00				
19	3	Grease	19	00				
20			19	00				
21			31	44				
22			30	00				
23	3	Waste	30	00				
24			30	00				
25			7	10				
26			7	00				
27	3	Gasoline	7	00				
28			7	00				
29			10	15				
30			10	00				
31	3	Kerosene	10	00				
32			10	00				
33			186	10				
34			170	00				
35	3	Packing	170	00				
36			170	00				
37			260	39				
38			230	00				
39	3	Lime	230	00				
40			230	00				
41			340	78				
42			230	00				
43	3	Ammonia	230	00				
44			230	00				

…rt should include P. W. A., W. P. A., or other emergency activities.

Total population
Mil. population
Avge. no. animals
No. hosp. beds

Quartermaster.

…ed:

(Commanding General).
(Commanding Officer).

3—6803
245260°—40 (Face p. 22…

[ ]HAT HAS BEEN OR IS TO BE ACCOMPLISHED

(See AR 30-1435 and AR 30-1760)
3—8603

S	F. Y. 1938	F. Y. 1939	F. Y. 1940	F. Y. ~~XXXX~~ 1942
overloaded. It has garrison increases, obably eventually be- sal plant, but for the d to collect waste ld parallel the final the river at the same				
d in service for about It has given ex- ensive system of dirt r landscaping, and in present calendar or new parts alone. A be procured for some				7,500.00
r driven street sweep- pressing requirement. Post is large, necess- leaning. Practically n this work with the other police work. free the greater part ork and return an				8,000.00
of the Post proper is over 2000 acres. re surrounded by nd costly trees and o be mowed and raked ition, the ranges limits of the Post and lawn mowers and are constantly in use. sickles, and tons of . It is impossible to nts and a special pro- to permit the purchase				10,000.00
of supplies, both to final carrier is a the local railroad ass B, when installed ed repairs but it is od serviceable con-				20,000.00

WAR DEPARTMENT
Q. M. C. Form 95
(Revised July 19, 1929)

Date of Report
(To be forwarded so as to reach O. Q. M. G.

Station Fort Benning, Ga.

Line No.	Project No.	Designation	Cost F. Y. (include under projects major work listed on reverse of sheet)		Work Accomplished: Unit	Operation—or $1,000 and under Repairs: No. of Units	Unit Cost
1			288	15			
2			255	00			
3	3	Chlorine	255	00			
4			255	00			
5			48	26			
6			50	00			
7	3	Soda, Ash	50	00			
8			50	00			
9			105	15			
10			105	00			
11	3	Soda Bicarbonat	105	00			
12			105	00			
13			519	56			
14			520	00			
15	3	Alum	520	00			
16			520	00			
17			192	45			
18			110	00			
19	3	Salt, rock	110	00			
20			110	00			
21			208	21			
22			208	00			
23	3	Charts	208	00			
24			208	00			
25			57	16			
26			55	00			
27	3	Polish, brass	55	00			
28			55	00			
29			10	26			
30			10	00			
31	3	Glasses,	10	00			
32		Steam Gauge	10	00			
33			6	10			
34			6	00			
35	3	Pens, steam flo	6	00			
36		meter	6	00			
37			120	56			
38			120	00			
39	3	Tetrachloride	120	00			
40			120	00			
41			55	30			
42			55	00			
43	3	Charges, Fire	55	00			
44		Extinguishers	55	00			

...t should include P. W. A., W. P. A., or other emergency activities.

Total population

Mil. population

Avge. no. animals

No. hosp. beds

Quartermaster.

...d:

(Commanding General).
(Commanding Officer).

THAT HAS BEEN OR IS TO BE ACCOMPLISHED (See AR 30-1435 and AR 30-1760) 3-8693

JECTS	F. Y. 1938	F. Y. 1939	F. Y. 1940	F. Y. ~~1941~~ 1942
ently needed, while the ess. Much of the sand air work comes in by ge and fuel, when issued, and condition of avail- s for the track scales. de at once and of the year.				
There are some 600 mech- eteria cooling units, stems for maintenance on r repairs, only one man intenance, and it is eep them up. Of the total tors which have been in cturer advises that sealed and no longer manufactured. air them locally. Since ve had to be charged. If refrigeration in the coming s be supplied for main- r supply of new boxes soon.				12,000.00
of heavy furniture for o be small, while main- use rises year by year. nts, minor breakage, d a continuous demand for listed personnel hereto- p up the requirements. ime cabinet repairman and be employed. The sal- at least $5,000.00 per			5,000.00	5,000.00
<u>TRIBUTION SYSTEM:</u> e largely been placed in yet remain on overhead be transferred to under- r economy and safety er can be accomplished, or, at a cost of some nto 3 sections, as follows: 10,138.00; on Wold from n Edwards from Wold to				30,021.00

WAR DEPARTMENT
Q. M. C. Form 95
(Revised July 19, 1929)

Date of Report
(To be forwarded so as to reach O. Q. M. G.

Station Fort Benning, Ga.

Line No.	Project No.	Project Designation	Cost F. Y. (include under projects major repair work listed on reverse of sheet)		Work Accomplished Unit	Operation—or $1,000 and under repairs No. of Units	Unit Cost	
1			22	10				
2			22	00				
3	3	Boiler Compound	22	00				
4			22	00				
5			58	27				
6			58	00				
7	3	Laboratory Suppli	58	00				
8			58	00				
9			2776	05				
10			2500	00				
11	3	Total of Project	2500	00				
12			2500	00				
13			3362	72				
14			3500	00				
15	5	Incandescent Lam	3500	00				
16			3500	00				
17			320	00				
18			320	00				
19	11	Rental,	320	00				
20		Right-of-Way	320	00				
21			660	00				
22			660	00				
23	2	Rental of Rooms	660	00				
24			660	00				
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								
41			01251	26				
42		Total of Operati	94030	48				
43			14685	48				
44			14685	48				

should include P. W. A., W. P. A., or other emergency activities.

Total population

Mil. population

Avge. no. animals

No. hosp. beds

Quartermaster.

(Commanding General).
(Commanding Officer).

3—86-13
245260°—40 (Face p. 22

HAT HAS BEEN OR IS TO BE ACCOMPLISHED (See AR 30-1435 and AR 30-1700)

TS	F. Y. 1938	F. Y. 1939	F. Y. 1940	F. Y. 1942
The Post is served by 2 separ ub-Station. When this s ago, voltage reg- e carried power only necessary to tie in on these circuits s be provided. They .00 for equipment and				6,300.00
uel gas ranges have and in a few of the number of aged elec- oal burning stoves bout half time of ic ranges along, and ipment. More than rts in the course of cost of repairs in- ted to permit a com-				7,000.00
INGS: The total irs under C & R of H rate letters submitted f his activity.				16,440.00

UTILITIES

OFFICE OF THE QUARTERMASTER GENERAL, CONSTRUCTION DIVISION, FUNDS AND ESTIMATE BRANCH

INSTRUCTIONS

On the Preparation of Defense of the Budget, Fiscal Year 1940

ANNUAL REPORT

MAINTENANCE, REPAIR, AND OPERATION—BUILDINGS AND UTILITIES

Q. M. C. Form No. 95. (Revised July 19, 1929.)
(United States Government Printing Office.)
(See AR 30–1435 and 30–1760.)

1. In the maintenance of utilities, repair and operation of buildings, structures, and systems coming under the jurisdiction of the Construction Division of the Quartermaster Corps, it is essential that reports of costs and operation data be prepared and submitted to The Quartermaster General for the following reasons:

To obtain data required for defending estimates before the War Department budget committees, the Director of the Budget and committees of Congress.

To obtain data for annual and special reports required by the War Department.

To determine whether posts, camps, and stations are being maintained properly and efficiently and in accordance with law.

To make comparisons of costs and maintenance results between stations, and in particular those stations receiving emergency funds.

To determine whether funds are being expended for the purpose authorized.

To obtain information upon which to base future maintenance policies.

To obtain the necessary data upon which to balance the annual appropriations and to make proper and equitable distribution of funds.

2. Q. M. C. Form 95 (Report of Maintenance—Repair and Operations) for defense of the budget is primarily a cost sheet. The information in this report will show just how and where authorized funds, personnel, fuel, surplus or salvage materials, etc., were used. Owing to the fact that enlisted labor is used wherever practical, funds are received from various sources, and surplus materials used, the actual cost of repair and operation does very often exceed the funds authorized. In many cases materials purchased one fiscal year are used in the next. Therefore columns have been provided to show actual cash spent from the appropriation, the value of surplus or salvaged materials, enlisted labor, and total cost.

3. It is essential that reports contain complete and accurate data and costs. Reports forwarded through corps area or department quartermasters should be verified as to correctness of totals and calculations. For exempted stations it is necessary for the quartermaster or utilities officer personally to provide this check. Where utilities officers, civil engineers, superintendents, or other

technical personnel are on duty at stations or corps areas or departments, a thorough study of the data contained in these reports should be made and the necessary steps taken to correct deficiencies.

4. Q. M. C. Form 95 should be forwarded so as to reach the O. Q. M. G. *not later than January 1, 1938.*

5. No letter of transmittal is necessary. All corrections, remarks, or recommendations should be made in red, or if sufficient space is not available a separate sheet should be added as an additional inclosure. Care should be taken when a correction has been made under a project to carry the correction through to the total. Difficulty has been experienced in the Office of The Quartermaster General through failure of some stations to do this, making it necessary for the entire report to be totaled in order to balance.

6. Reports should contain costs and data pertaining to all maintenance, repair, and operation projects handled by the quartermaster, even though the work is being performed for other branches of the War Department and from other than Q. M. C. funds.

Particular attention should be given to the value of the assistance received through emergency funds and agencies. Report should be made under each and all emergency appropriations if assistance has been received or funds allotted, in the same manner as any other appropriation, and a total shown for each emergency appropriation.

7. Reports will be required for all posts, camps, stations, landing fields, airdromes, etc., wherever funds are expended. This will also include ungarrisoned stations where only caretakers are employed. Corps area and department commanders will submit a consolidated report for the entire area or department. This consolidated report should represent requirements as visualized by the corps area or department commander. The station reports will be attached to the consolidated report as an inclosure and forwarded through military channels to this office.

8. Reports of maintenance—repair and operation, should be compared at frequent intervals with cost reports of public utilities companies and contractors making similar reports or operating similar utilities to see if United States repair and operation compares favorably with commercial practice. The result of these comparisons should be forwarded with this report on letter size sheets. These data are needed to show that the United States is operating as economically as commercial firms. The data covering fiscal year 1939 allotments and fiscal year 1940 requirements should be based on current quotations.

9. One report, Q. M. C. Form 95, will be required annually so as to reach the quartermaster general not later than January 1st. This is in accordance with instructions contained in AR 30–1760. Paragraphs 10 to 33, inclusive, explain the entries that are required under the various columns.

10. Insert the name of the station, page number, and the date on which the report was prepared in the blank spaces provided for this purpose.

11. Columns and lines for four fiscal years have been provided opposite each project for information that is required to defend budget estimates. Therefore, it will be necessary to make an entry in each column where applicable. No entry will be construed by the O. Q. M. G. as meaning no cost and no data available or no funds required.

12. The four fiscal years shown cover the actual expenditures made during the fiscal year 1937, the estimated total annual expenditure for fiscal year 1938

to be based on fiscal year 1938 funds already allotted to the field, including also all expected help through emergency funds and agencies (it will be noted that this entry calls for a full year's estimate, not 6 months), the estimated amount of funds that are required for the fiscal year 1939 and the amounts that the station and corps area and department commanders request to be estimated for in the budget estimate that will be presented to Congress covering the fiscal year 1940.

13. Under the heading "project" will be shown—

(*a*) The number of the project as carried in the fiscal year 1938 budget.

(*b*) The designation of the project as used in the fiscal year 1938 budget.

(*c*) The appropriation under which the project is defended.

The information under (*a*), (*b*), and (*c*) above is shown in a subsequent paragraph and is also covered in your annual letter of information fiscal year 1938 allotments.

14. Under the heading "cash from appropriation" will be shown, as its heading implies, actual or estimated expenditures from appropriations, as follows:

(*a*) Under "civilian labor" will be shown the cost of all overhead and operating employees considered as regular annual permanent personnel, funds for which are authorized under project No. 1 and payments made under purpose number 1-0110. This information will be shown opposite project No. 1. Where allowances are authorized in addition to cash salaries, the value thereof will be shown under the column headed "value of surplus or salvaged materials, fuels or supplies." The addition of the cash salary plus the value of the allowance will give the amount that should be shown in the column "total cost fiscal year."

(*b*) Under "civilian labor" will also be shown the cost of all employees used on repair work other than those listed under project No. 1, funds for which were authorized under repair projects and payments made under purpose numbers pertaining to repair and alteration, such as 12-1200, 13-1210, 14-1220, etc. The cost will be prorated and shown opposite each project on which they are applicable. Do not confuse project No. 1 personnel and repair personnel; they should be shown as separate and distinct charges.

(*c*) Unloading coal and personnel services in connection with same should be shown under "civilian labor" when work is performed by day labor (hired specifically as personnel and paid by the Government), and under "contract" when performed under contract (as a nonpersonal service).

(*d*) Under "materials or supplies" will be entered the cost of materials or supplies actually purchased or estimated as required. This cost should be distributed through the various projects to which they pertain. In order to balance the funds expended for materials or supplies with the amounts shown on purchase orders, it will be necessary to have a separate project covering the value of materials or supplies purchased from fiscal year 1937 funds but not utilized during fiscal year 1937, from which amount will be subtracted the value of the materials or supplies purchased in fiscal year 1936 from fiscal year 1936 funds, but not used in fiscal year 1936 and carried over into fiscal year 1937. The net result, either plus or minus, will be included in fiscal year 1937 total, and if a plus will be carried over to the fiscal year 1938 report when preparing the 1941 Form 95.

(*e*) Under "fuel" should be shown the cost f. o. b. station of the various hard and liquid fuels that were purchased or estimated as required and the value distributed under the projects as listed in subsequent paragraphs.

(*f*) Under "contracts" should be shown the cost of the service contracts for gas, electricity, water, heat, fire alarm, clock regulation service, sewage service, etc., and such maintenance and repair or major contracts that have been or will be accomplished from maintenance and repair funds. The amounts of these maintenance and repair contracts should be distributed under the various projects to which they pertain.

(*g*) Under "total," the sum of the preceding columns should be typed. This represents the total cash expended and should agree very closely with funds reported by purpose numbers on quarterly reports and Procurement Authority Forms 23 and 23A. The total cost under any projects should agree insofar as practicable with the expenditures as shown by purpose numbers that are applicable to this project. It is very important for this office to have these figures agree, due to the fact that when estimates are presented to the Budget Officer of the War Department (who is also the Chief of Finance) a check is made with the books of his office. The records in the office of the Chief of Finance show all the procurement authorities issued to field stations and the exact expenditures made by finance officers against these same procurement authorities; therefore, if the figures presented by this office are in disagreement with those of the office of the Chief of Finance, it requires much checking and explaining to rectify errors.

15. Under the heading "value of enlisted labor" should be shown the equivalent cost based on 35 cents per hour (estimated as the value of replacing enlisted labor by civilians) for each enlisted man when actually on duty in connection with maintenance. This would include also enlisted men of organizations that are assigned to the quartermaster from time to time and enlisted men of organizations doing repair work when not assigned to the quartermaster, in addition to the regular Quartermaster Corps enlisted personnel.

16. Under the heading "value of surplus or salvaged material, fuel or supplies" should be shown the amount of money that would be required to purchase the same articles f. o. b. station in the same condition at the time they were used or expected to be required. Good materials, supplies, etc., used from stock which were purchased during prior fiscal years should be shown at invoiced price. Where this is not known, market values prevailing during the period of consumption should be used in calculating cost.

17. Under "total cost, fiscal year," should be shown the entire cost of the project. It should include the cash spent from the appropriation, the value of enlisted labor, and the value of surplus or salvaged supplies or those that were on hand, having been purchased from previous fiscal year funds. This column should represent the "total cost." This means ordinary repairs as well as major projects listed on the reverse side of the sheet that require the approval of the commanding officer, corps area or department commanders, and the Secretary of War. The total cost should also include all repairs under emergency appropriations whatever their source.

18. Under the heading "work accomplished" will be shown what was done with the money expended or what it is expected to do with the money esti-

mated for; thus, under "water" will be shown the number of M gallons used or estimated as required; under "repair projects," the number of buildings or utilities actually repaired ($1,000 or under) or estimated as required. The units that are to be reported on are shown in subsequent paragraphs under each project.

19. On the reverse side of the report will be shown major repair work but not new construction over $1,000. The cost of this major repair work plus the cost of the work accomplished, $1,000 or under (as shown under "work accomplished") must equal the "total cost, fiscal year." AR 30–1760 now provides that Q. M. C. Form 105 will not be submitted with and at the same time as Q. M. C. Form 95. It therefore will be necessary to furnish a clear letter description of the project for fiscal years 1939 and 1940 which will indicate their relative importance when compared one station with another. For those projects completed fiscal year 1937 and under way fiscal year 1938, a brief description only is necessary. Q. M. C. Form 105 should not be prepared until after funds have been allotted or advice of allotment received. It is desired to call your attention again to the fact that the projects listed on the reverse side of Form 95 must be included in the totals as shown under each project. The information on the reverse side of this form is descriptive only. The cost of the various projects is tabulated, and then of this total cost a certain percentage are major projects all as listed on back of forms and so reported. If the cost of these major projects has been omitted in the project, there is a possibility that they will not be considered.

Total costs must include everything, major repairs listed on backs of the form as well as minor repairs $1,000 or under, together with the value of work accomplished from allotments or assistance received through emergency relief appropriations (not regular appropriations), regardless of their source, whether from Federal allotments or through local administrators. New construction must be submitted by letter as a special case.

20. In reporting "total population" the average for the fiscal year 1937 will be considered. By total population is understood the entire average population of post or station and should include officers and their families, servants, and civilian employees. By military population is understood commissioned officers, noncommissioned officers and enlisted men, also military prisoners of the regular establishment. (N. R., R. O. T. C., C. M. T. C., and O. R. military population should be stated separately.)

21. Report the average number of animals covering the fiscal year 1937.

22. Under "number of hospital beds" should be shown the maximum number that were available fiscal year 1937.

23. Report per capita costs of "operation" and "repair" also total per capita cost of maintenance in proper space; these costs to be based on military population only as shown on the report.

24. Per capita consumption of water, electricity, gas and electric lamps should be shown in proper blanks; these per capitas to be based on military population only as shown on this report.

25. Maintenance work should be accomplished in accordance with the following Army Regulations:

30-1435	30-1475	30-1505	30-1515	30-1580
30-1620	30-1625	30-1635	30-1660	30-1670
30-1675	30-1680	30-1685	30-1690	30-1710
30-1715	30-1760	30-1770	30-1775	40-585

and only by the authority of the quartermaster or his authorized representative, and the cost of all work thus performed should be entered on Work Order, Form 106, in accordance with instructions on the preparation and use of the Work Order, Form 106.

26. Special attention is invited to the fact that all past and current expenditures or the value thereof should be shown on this report the same as any other appropriation, covering appropriations under the following titles: C. C. C., W. P. A., Emergency Relief Appropriations, State assistance under W. P. A., and any other appropriation or source from which the post received assistance. A separate sheet should be inserted for each of the emergency appropriations, dividing them into the same projects as the regular barracks and quarters, Army, and construction and repair of hospitals, Army, are divided. In other words these expenditures should be set up as a comparison to the regular appropriations, showing in detail under each project the actual amount expended in the fiscal year 1937, estimated expenditures during the fiscal year 1938, and the funds which the station, corps area, or department commander believes could be utilized from emergency appropriations if such funds become available.

27. All the projects listed in subsequent paragraph are defended by the Construction Division. These estimates must be defended before The Quartermaster General, the War Department Budget Advisory Committee, the Director of the Bureau of the Budget, House and Senate Appropriation Committees of Congress. Therefore, there should be realized the great amount of detailed data that this office must prepare to explain fully each project in order to secure the necessary funds for Quartermaster Corps activities.

It is urged that all quartermasters give budget estimates their personal attention so that this office will be in a position to state facts and the exact requirements of the field, neither exaggerating nor minimizing them.

28. On or about June 1, 1938, each corps area, department, or exempted station commander will be advised as to the amount of money that it is expected will be allotted for the fiscal year 1939.

29. Attention is invited to the fact that no entries should be shown for packing and crating of household effects incident to the movement of personnel. Funds for this purpose, covering purchase of materials and hire of labor, are furnished by the Supply Division, and in addition the regular post mechanics are also used. Therefore, unless it has been necessary to use B. and Q. funds for this purpose, this project should not be reported on Q. M. C. Form 95.

30. Please note that each station report as well as the corps area consolidated report should have three totals, one covering operating expenditures, one repair expenditures, and a grand total covering both. These totals should show correct addition.

31. If on the consolidated report, signed by the corps area quartermaster and the commanding general, no mention is made of special projects over $1,000, it will be presumed that the corps area commander approved the requests

of the commanding officer on station report. In the event the corps area commander does not approve the station commander's request, the disapproval and reason should be indicated in order that this office when authorizing additional funds or estimating for the 1940 budget may act in accordance with the wishes of the corps area commander.

32. Your attention is invited to letter from the Chief of Staff to all corps area and department commanders, chiefs of all War Department branches, the commandant, Army War College, the superintendent, U. S. Military Academy, the commandant, Command and General Staff School, Fort Leavenworth, Kansas, and the commanding general, GHQ Air Force, Langley Field, Virginia, dated June 8, 1936, and its amendments in connection with the management of national defense funds and property. Particular attention is invited to the 4-year repair program called for.

33. Special attention is invited to paragraph 21 of letter from this office dated June 1, 1937; subject: Annual Fiscal Year 1938 Allotments for Maintenance—Repair and Operation of Buildings and Utilities (file QM 121.2 C-F):

> 21. It is requested that on or after January 2, 1938, this office be furnished a list of projects in priority sequence that your office desires to be considered for the distribution of any funds still held in the Secretary of War's reserve, or that may become available for allotment through savings or reimbursements. This list must be received in the Office of The Quartermaster General not later than January 31, 1938. In preparing such priority list, attention should be given to necessary repairs and utilities. No new construction nor major additions should be considered unless they have the prior approval of the War Department. The list should be supported with QMC Form 105, sketch-photos, etc., if not already available in this office. The Office of the Quartermaster General bases all its recommendations to the War Department upon these lists, hence great care should be exercised in preparing them.
>
> Particular attention should be given to the priority numbers, and their priority sequence should be approved by the commanding officer, as it is planned by this office, insofar as funds will permit, to follow if possible the priorities of each commander in connection with their relationship to the same priority numbers of other commanders throughout the United States and departments.

Projects To Be Estimated for

by

THE CONSTRUCTION DIVISION

QUARTERMASTER GENERAL

Fiscal Year 1940

The following is a list of the projects that must be reported upon if any expenditures have been made in fiscal year 1937 or expected to be made fiscal year 1938, or if funds are needed during the fiscal years 1939 and 1940.

MILITARY OPERATION

A Project No. as shown in fiscal year 1938 budget	B Designation and description of the project	C The unit that will be reported upon in the column "work accomplished"
	FUEL—LIGHT AND POWER	
	APPROPRIATION—ARMY TRANSPORTATION, WATER—	
12	Fuel in kind—Required for the operation of harbor boats; limited to expenditure under purpose numbers 12-0230 and 12-0700: Coal. Gasoline and oil.	No unit required. Funds to check with detailed data on Q. M. C. Form 108 and annual requisition.
	APPROPRIATION—ARMY TRANSPORTATION, MOTOR	
35	Services—Required in the operation of motor-transport shops as follows; limited to expenditure under purpose No. 35-1020: Electricity (purchased, not generated). Fuel gas.	No unit required. Funds to check with detailed data on Q. M. C. Form 108 and annual requisition.
	APPROPRIATION—ARMY TRANSPORTATION, RAIL	
74	Fuel in kind—Required for the operation of locomotives and cranes, limited to expenditure under purpose Nos. 74-0230 and 74-0700: Coal and wood. Gasoline and oil.	No unit required. Funds to check with detailed data on Q. M. C. Form 108 and annual requisition.
63	Handling of coal and personal services in connection with same—Limited to expenditure under purpose No. 63-0700.	
	APPROPRIATION—BARRACKS AND QUARTERS, ARMY	
2	Fuel in kind—Required for heating, cooking, and fortification power plants; electric generating plant; for ice-making plants, pumping, refrigeration, and incinerator plants; road rollers and machinery; fire apparatus, including purchase of heat and smithing coal for shoeing animals, etc.; and kerosene for lamps and lanterns; limited to expenditure under purpose Nos. 2-0230 and 2-0700:	No unit required. Funds to check with detailed data on Q. M. C. Form 108 and annual requisition.

A Project No. as shown in fiscal year 1938 budget	B Designation and description of the project	C The unit that will be reported upon in the column "work accomplished"
	APPROPRIATION—BARRACKS AND QUARTERS, ARMY—Continued	
	Coal, coke, wood, peat, and other solids. Electricity (purchased, not generated). Gas (purchased, not generated). Heat—Required where steam is purchased from a public utilities company or other branch of the Government or where electricity is purchased and required for heating-valve houses in connection with sprinkler systems for fire prevention. Kerosene for lamps and lanterns—Required for illumination at places and stations where electricity is not available or cannot be used. Gasoline, fuel oils, and like products.	
6	Purchase of electric current for light and power (not generated)—Required for lighting and power; in the operation of motors used in heating and lighting plants, feed water and vacuum pumps, converters, fans, blowers, coal and ash hoists, stokers, elevators, shops, sawmills, ventilating appliances, office machines, clippers, forage cutters, doughmixers, meat choppers, ice-cream freezers, dish washers, potato peelers, printing machines; also for purchasing electric current for films or slides for instruction of military personnel; water pumping, boosting, filtering, and treating plants; ice and refrigeration plants; sewage-disposal plants, incinerators; mechanical refrigerators; quarries; gravel pits; air compressors; stone crushers; swimming pools; and such other miscellaneous use as required by the Quartermaster Corps, limited to expenditure under purpose Nos. 6-1010 and 6-1030.	No unit required. Funds to check with detailed data on Q. M. C. Form 108 and annual requisition.

A Project No. as shown in fiscal year 1938 budget	B Designation and description of the project	C The unit that will be reported upon in the column "work accomplished"
	APPROPRIATION—CLOTHING AND EQUIPAGE, ARMY	
9	Fuel and power service—Required in the operation of laundries as follows: Fuel in kind—Limited to expenditures under purpose numbers 9-0230 and 7-0700. Coal, coke, wood, peat, and other solids. Gasoline, oil, and like products. Fuel gas. Electricity (purchased, not generated)—Limited to expenditure under purpose number 9-1020.	No unit required. Funds to check with detailed data on Q. M. C. Form 108 and annual requisition.
	OTHER OPERATION PROJECTS	
	APPROPRIATION—BARRACKS AND QUARTERS, ARMY	
1	Salaries—General overhead and operating personnel: Regular permanent annual personnel—Limited to expenditure under purpose number 1-0110.	Number of employees.
3	Operating supplies—Required in the operation of heating, lighting, power, pumping, ice, refrigeration, incinerator and sewage disposal plants, and for fire apparatus, modern batteries, and mechanical refrigerators (see Cir. 1-6, July 15, 1935): Lubricating oils, waste, grease, boiler compound, packing, chlorine, soda ash, lime, alum, calcium, copper sulphate, bicarbonate of soda, sulphuric acid, extinguishing liquid, nonfreezing and polishing materials, gauge glasses, meter ink, charts, valve springs, etc.—Limited to expenditure under purpose number 3-0282.	No unit required. Funds to check with plant operating reports and requisitions.
5	Incandescent lamps—No funds have been allotted for incandescent lamps as purchases of lamps are made through The Quartermaster General's Office based on the annual requisitions received. Lamps, when purchased, will be forwarded direct to your station, except emergency purchases (Chg. 1, Cir. 1-4, 7-1-35, par. 28), P 5-0282.	No unit required. Funds to check with data on your annual requisition for lamps.

A Project No. as shown in fiscal year 1938 budget	B Designation and description of the project	C The unit that will be reported upon in the column "work accomplished"
	APPROPRIATION—BARRACKS AND QUARTERS, ARMY—Continued	
7	Removal of garbage—For the payment of services for removal of garbage, including the removal and disposition of dead animals, where it cannot be sold, given away, or where facilities are not available or practical for its incineration, limited to expenditure under purpose number 7–1375.	No unit required.
	Transportation of operation materials and supplies from point of origin to first point of delivery—Limited to expenditure under purpose number 0700, the prefix to be determined by the project under which the transportation is required.	No unit required.
9	Water (purchase)—Limited to expenditure under purpose number 9–1040.	1,000 gallons.
10	Hire of recruiting stations and lodgings for recruits in accordance with the approval of The Adjutant General's Office, Recruiting Service—Limited to expenditure under purpose number 10–1100 (must check with reports of corps area recruiting officer.)	No unit required.
11	Rental of buildings, offices, quarters, storage space, stall space, camp sites, grounds, cold storage, and rights of way—Limited to expenditure under purpose numbers 11–1100 and 11–1111 (must check with approved rentals).	No unit required.
12	Window washing (under contract)—Limited to expenditure under purpose number 12–1200.	Do.
14	Purchase or procurement of sewer or sewage-disposal service (usually paid to city or town or other department for privilege of using their sewer or of pumping or disposing of the post sewage)—Limited to expenditure under purpose number 14–1220.	1,000 gallons or flat charge.
16	Rental of fire-alarm boxes and clock-regulation service—Limited to expenditure under purpose number 16–1280.	No unit required.
	APPROPRIATION—CLOTHING AND EQUIPAGE, ARMY	
9	Water (purchased)—Required for laundry operation—Limited to expenditure under purpose number 9–1040.	1,000 gallons.

A Project No. as shown in fiscal year 1938 budget	B Designation and description of the project	C The unit that will be reported upon in the column "work accomplished"
	APPROPRIATION—CONSTRUCTION AND REPAIR OF HOSPITALS, ARMY	
1	Salaries—Technical, clerical, and key regular annual personnel—Limited to expenditure under purpose number 1-0110.	Number of employees.
2	Rental of buildings, rooms, and grounds for hospital purposes (prophylactic stations)—Limited to expenditure under purpose numbers 2-1100 and 2-1111.	No units required.

Report on all other appropriations pertaining to other War Department branches which are handled by the quartermaster, covering rentals, heat, light and power, service contracts, operating supplies, etc.; also on all operating funds used or value of services received from any of the relief agencies.

REPAIRS

	APPROPRIATION—BARRACKS AND QUARTERS, ARMY	
12	Maintenance, alteration, and repair of buildings, as follows—(Includes purchase of material, the hire of personnel, and other expenses necessary for repair to roofing, painting, flooring, doors, windows, window washing, plastering, masonry, chimneys, mill work, porches, downspoutings, roof-guttering, structural iron work, sheet metal work, screen doors, screen windows, window shades, surveys, and boundary markers, repairs to surveying instruments, flooring and framing of tents, etc., and plumbing, heating and electric wiring and fixtures in buildings up to 5 feet outside of the building line)—Limited to expenditures under purpose number 12-1200:	
	Military post exchange buildings	Number of buildings.
	Chapels	Do.
	Organ tuning	Number of organs.
	Schools (children's schools (not enlisted) all grades).	Number of buildings.
	Schools (enlisted men's service schools)	Do.
	Other amusement buildings, libraries, gymnasiums, service clubs, etc.	Do.
	Bakery buildings	Do.
	Ice and refrigeration plant buildings	Do.
	Laundry buildings	Do.
	Reservation and interior fences	Number of miles.
	Flagstaffs	Number of flagstaffs.
	Permanent barracks	Number of buildings.
	Temporary barracks	Do.

A Project No. as shown in fiscal year 1938 budget	B Designation and description of the project	C The unit that will be reported upon the column "work accomplished"
	APPROPRIATION—BARRACKS AND QUARTERS, ARMY—Continued	
12	Maintenance, alteration, etc.—Continued.	
	Permanent officers' quarters	Number of buildings.
	Temporary officers' quarters	Do.
	Permanent warrant officers' quarters	Do.
	Temporary warrant officers' quarters	Do.
	Permanent noncommissioned officers' quarters.	Do.
	Temporary noncommissioned officers' quarters.	Do.
	Stables	Number of stables.
	Garages	Number of buildings.
	Permanent nurses' quarters	Do.
	Temporary nurses' quarters	Do.
	Indoor shooting galleries	Number of galleries.
	Target ranges; buildings and shelters	Number of buildings.
	Target butts	Number of targets.
	All other miscellaneous permanent buildings (other than hospital or technical buildings of other War Department branches).	Number of buildings.
	All other miscellaneous temporary buildings (other than hospital or technical buildings of other War Department branches).	Do.
	Flour for target paste	Pounds.
	Tent frames and floors	Number of each.
	Miscellaneous (list in detail)	Units to suit.
13	Maintenance and repair of roads, walks, drainage, railroads and dredging, as follows—Limited to expenditure under purpose number 13-1210:	
	Roads	Miles.
	Walks	Do.
	Drainage (storm water)	Do.
	Dredging channels pertaining to Q. M. C.	Cubic yards.
	Care and improvement to grounds	Acres.
	Mosquito prevention works.	
	Bridges and culverts.	
	Railroads (Q. M. C. only)	Miles.
	Track scales	Each showing capacity.
	Wagon and truck scales	Do.
	Retaining walls, sea walls, and embankments.	Cubic yards.
	Special—roads, Ft. Monroe (formerly under sewerage system, Ft. Monroe, Va.), Third Corps Area only.	
14	Maintenance and repair of water and sewer systems as follows—Limited to expenditure under purpose number 14-1220:	
	Water mains	Miles.
	Sewer mains	Do.

A Project No. as shown in fiscal year 1938 budget	B Designation and description of the project	C The unit that will be reported upon the column "work accomplished"
	APPROPRIATION—BARRACKS AND QUARTERS, ARMY—Continued	
14	Maintenance and repair, etc.—Continued.	
	Sprinkler systems	Linear feet.
	Water pumping and treating plants	Number of plants and gallons per minute.
	Water tanks	Number of tanks.
	Special—sewer system, Fort Monroe (formerly under sewerage system, Fort Monroe, Va.), Third Corps Area only.	
	NOTE.—Plumbing repairs are to be charged to building to which they pertain and accordingly should be included in estimate under project 12 and not project 14.	
15	Maintenance and repair of wharves—Limited to expenditure under purpose No. 15-1240:	
	Wharves (Q. M. C.)	Square feet.
	Special—wharves, Fort Monroe (formerly under sewerage system, Fort Monroe, Va.), Third Corps Area only.	
16	Maintenance and repair, fire apparatus, as follows—Limited to expenditure under purpose No. 16-1280:	
	Motor-driven fire apparatus including the chassis.	Number of apparatus.
	Fire extinguishers	Number of extinguishers.
	Fire-alarm system.	
	Hose carts and reels (hand-drawn)	Number of each.
	Miscellaneous apparatus (list separately)—Ladders, axes, etc.	Do.
17	Maintenance and repair, heat, and power plants, etc., as follows—Limited to expenditure under purpose No. 17-1280:	
	Sewage pumping and disposal plants	Number of plants, gallons per minute or M gallons per day.
	Incinerators (includes can washers, if any).	Number of plants and tons.
	Central heating and power plants	Number of plants and horsepower.
	Central heating plant distribution system	Linear feet of distribution system.
	Steam or hot-water mains connecting plant with buildings. (Do not include heating equipment nor heating apparatus in individual quarters or buildings.)	
	Ice and refrigeration plants (including cold-storage room and equipment; also including electric water coolers).	Number of plants and tons of refrigeration or ice.

A Project No. as shown in fiscal year 1938 budget	B Designation and description of the project	C The unit that will be reported upon the column "work accomplished"
	APPROPRIATION—BARRACKS AND QUARTERS, ARMY—Continued	
17	Maintenance and repair, etc.—Continued.	
	Gasoline storage plants	Number of plants and gallons of gasoline.
18	Maintenance and repair—refrigerators, wall lockers, and furniture, as follows—Limited to expenditure under purpose number 18–1280:	
	Refrigerators (ice-cooled)	Number of refrigerators.
	Refrigerators (mechanical)	Do.
	Wall lockers in barracks	Number of lockers (double lockers to be considered as 2; triple lockers as 3, etc.).
	Heavy furniture in officers' quarters and messes, warrant officers' and noncommissioned officers' quarters.	Number of pieces.
19	Maintenance and repair of electric gas systems, as follows—Limited to expenditure under purpose number 19–1290:	
	Electric generation plants	Number of plants and kilowatts.
	Electric motors	Horsepower.
	Electric substations	Number and kilowatts.
	Electric street lighting systems	Miles and number of lamps.
	Electric transmission and distribution system.	Miles.
	Maintenance and repair, electric fans	Number of fans.
	Purchase of electric fans	Do.
	Maintenance and repair, electric bells and buzzer systems.	Number of bells and buzzers.
	Gas systems	Miles.
	NOTE.—Repair to lighting or gas fixtures to be charged to buildings to which it pertains.	
	Transportation of repair materials and supplies from point of origin *to first point* of delivery—Limited to expenditure under purpose number 0700, the prefix to be determined by the project under which the transportation is required.	Number of tons.
20	Purchase of wall lockers as replenishment in permanent barracks.	Number of units required.
21	Purchase of heavy furniture as replacements or to meet existing shortage as follows:	Do.
	For officers' quarters and messes, warrant officers' and noncommissioned officers' quarters.	

A Project No. as shown in fiscal year 1938 budget	B Designation and description of the project	C The unit that will be reported upon the column "work accomplished"
	APPROPRIATION—BARRACKS AND QUARTERS, ARMY—Continued	
22	Purchase of refrigerators for replenishment as follows:	Number of units required.
	For officers' quarters and messes, warrant officers' quarters, noncommissioned officers' quarters and for barracks messes (list separately under ice-cooled and mechanical).	
23	Purchase of fire apparatus as replacements or to cover present shortage as follows:	
	Motor-driven pumping engines and apparatus (assembled by Q. M. C. at Holabird).	Number of engines. Funds to check with requisition submitted for this class of equipment.
	2½-inch standard fire hose (purchased through O. Q. M. G.).	Linear feet. Funds to check with requisitions.
	Nonstandard size fire hose (purchased locally) (when authorized by Q. M. G.).	Linear feet.
	2½-gallon soda and acid extinguishers (purchased through O. Q. M. G.).	Number of extinguishers. Funds to check with requisitions.
	2½-gallon foam extinguishers (purchased through O. Q. M. G.).	Do.
	1 gallon carbon tetrachloride extinguishers (purchased through O. Q. M. C.).	Do.
	Miscellaneous apparatus (list each) (purchased through O. Q. M. G.).	Number. Funds to check with requisitions.
24	Maintenance and repairs to stoves and ranges as follows (includes labor and material)—Limited to purpose number 24-1280:	
	Heating stoves	Number of stoves.
	Laundry stoves	Do.
	Cooking stoves	Do.
	Ranges, coal (state size)	Number of ranges.
	Ranges, electric (state size)	Do.
	Ranges, gas (state size)	Number of ranges.
	Ranges, oil (state size)	Do.
	Post bakery ovens (state size)	Number of ovens.
	Post bakery equipment (list)	Number.
	Miscellaneous equipment (list):	
	Screens, fire sets, andirons, etc. (but not kitchen equipment, such as pots, pans, etc.).	Do.
24	New equipment (list kind)—Limited to purpose number 24-3051.	Do.
25	Maintenance and repair of warehousing equipment, etc., as follows—Limited to purpose number 25-1280:	
	Warehouse equipment (list)	Do.

A Project No. as shown in fiscal year 1938 budget	B Designation and description of the project	C The unit that will be reported upon the column "work accomplished"
	APPROPRIATION—BARRACKS AND QUARTERS, ARMY—Continued	
25	Maintenance and repair, etc.—Continued.	
	Appliances for handling and preparation of fuel (list).	Number.
	Storage batteries	Do.
	Watchman's clocks	Do.
	Any other (list)	Do.
26	New equipment (list kind)—Limited to purpose number 25-3053.	Do.
	APPROPRIATION—CONSTRUCTION AND REPAIR OF HOSPITALS, ARMY	
3	Maintenance, alteration and repair of buildings as follows—Limited to expenditure under purpose number 3-1200:	
	Permanent post hospital buildings (including hospital stewards' quarters).	Number of buildings.
	Temporary post hospital buildings (including hospital stewards' quarters).	Do.
	Permanent veterinary hospital buildings	Do.
	Temporary veterinary hospital buildings	Do.
	All permanent buildings at general hospitals (to be divided into groups similar to those shown under project 12, barracks and quarters).	Do.
	All temporary buildings at general hospitals (to be divided into groups similar to those shown under project 12, barracks and quarters).	Do.
4	Maintenance and repair of roads, walks, and drainage at general hospitals only, as follows (station hospital at Fort Sam Houston to be considered as a general hospital and included under projects for general hospitals)—Limited to expenditure under purpose number 4-1210:	
	Roads	Miles.
	Walks	Do.
	Drainage (storm water)	Do.
	Care and improvement of grounds	Acres.
	Mosquito prevention work.	
5	Maintenance and repair of water and sewer systems at general hospitals only, as follows (station hospital at Fort Sam Houston to be considered as a general hospital and included under projects for general hospitals)—Limited to expenditure under purpose number 5-1220:	
	Water mains	Miles.
	Sewer mains	Do.

A Project No. as shown in fiscal year 1938 budget	B Designation and description of the project	C The unit that will be reported upon the column "work accomplished"
APPROPRIATION—CONSTRUCTION AND REPAIR OF HOSPITALS, ARMY—Continued		
5	Maintenance and repair, etc.—Continued.	
	Water pumping and treating plants	Number of plants and gallons per minute.
	Incinerators	Number of plants and tons.
	Sewage pumping and disposal plants	Number of plants and gallons per minute per day.
6	Maintenance and repair of heating, electric, and gas systems at general hospitals, and equipment at station and general hospitals, as follows—Limited to expenditure under purpose number 6–1280:	
	Central heating and power plants	Number of plants and horsepower.
	Central heating plant distribution system.	Linear feet of distribution system.
	Electric street lighting systems	Miles and number of lamps.
	Electric transmission and distribution system.	Miles.
	Gas systems	Do.
	Miscellaneous equipment (list where not covered under other construction and repair of hospital projects, such as ice and refrigeration plant equipment, motors, ranges, stoves, bakery equipment, electric generators, gas apparatus, etc.).	Number.

EMERGENCY APPROPRIATIONS

C. C. C., Work Relief, W. P. A., etc., and all other emergency agencies appropriation or assistance given—Consider the same as any other appropriation, show it by appropriate letters in the appropriation column, and report it in the same order and under the same projects as barracks and quarters, construction and repair of hospitals, etc.

WAR DEPARTMENT
. M. C. Form No. 108
Approved May 24, 1926

BUILDING INSPECTION REPORT

Station Ft. Dix, N. J.

st No. of building 121 Date first inspection 1/5/40 Date last inspection

ccupied by Capt. H. F. Jones From 1/5/40 To

NOTE.—Express the degree or condition of items by initials of the words: Excellent, very good, good, fair, poor, and worthless. "P" should be used when items could be repaired and "W" when items are not worth repair. Indicate condition of items when turned over to incoming tenant in column 1, and when building is being vacated indicate condition in column 2. Show money value of damages other than fair wear and tear opposite appropriate items in column 3. If condition of items is bettered during occupancy, appropriate notations should appear in space provided for remarks.

BUILDING	1	2	3
lls	G		
ilings	G		
oors	F		
of	G		
rches	G		
ors	F		
ndows	G		
rm windows	-		
ndow screens	F		
or screens	F		
rch screens	F		
ndow shades	F		
irways	G		
rtain poles	G		
terior paint	F		
terior paint			
nitation			

FURNITURE	1	2	3
Dining table	G		
Side chairs	G		
Armchairs	F		
Rocking-chairs	-		
Sideboards	F		
Library desks	G		
Library chairs	G		
Library tables	F		
Parlor tables	G		
Bookcases	-		
Chest drawers	G		
Kitchen tables	F		
Dressers	G		
Davenports	-		
Bedsteads	-		
Hatracks	-		
Wall lockers	-		

EQUIPMENT	1	2	3
Heating system:			
Grates			
Burners			
Flues			
Coverings			
Piping			
Blowers			
Hot-water system:			
Grates	F		
Burners	-		
Flues	G		
Coverings	G		
Piping	G		
Cooking ranges:			
Grates			
Burners			
Electric elements			
Cooking tops	F		
Oven linings	F		
Switches			
Gas cocks	G		
Hinges	G		
Stovepipe	F		
Gas piping	G		
Electric wiring			
Electric system:			
Wiring	G		
Fixtures	G		
Motors	-		
Fuses	G		
Lamps	G		
Switches	G		
Plumbing system:			
Bathtubs	G		
Washbasins	G		
Laundry tubs	G		
Urinals	-		
Sinks	G		
Fittings	G		
Refrigerators	G		
Utensils	-		

	SUPPLIES ON HAND			SERVICE METER READINGS		
	COAL (Lbs.)	WOOD (Cords)	OIL (Gals.)	ELECTRIC POWER	ELECTRIC LIGHT	GAS
ccupying						
acating						

isposition of keys

REMARKS: (NOTE.—Information needed to clarify or explain entries.)

The above entries indicate the true condition of building, furniture, and equipment.

(Signed) F. D. Smythe, Maj., QMC.
(Signature quartermaster)

I agree to the above report {without / ~~with the following~~} exceptions:

(Signed) H. F. Jones, Capt. Inf.
(Signature responsible occupying tenant)

I agree to the above report {without / with the following} exceptions:

(Signature responsible vacating tenant)

245260°—40 (Face p. 240) No. 1

ANNUAL REPORT OF CONSTRUCTION AND REPAIR

Fiscal year ending June 30, 19 39

FIRST (C. A.) (Depot) Station FORT WILLIAMS, MAINE

(1) Building No.	Desc	(6) Original Including to June 30, Fiscal Year		(7) Cost of New Construction (Including Alterations and Additions but not Repairs) During the Present Fiscal Year		(8) Replacement Value June 30, 19 39 Present Fiscal Year	
				$		$	
16	O F F	3077	50			7176	73
17	O F F	3077	59			7176	73
18	O F F	3255	00			7388	07
19	O F F	3255	00			7388	07
20	F I E	203	00			25076	79
21	F I E	203	00			25076	79
23	F I E	807	00			26428	79
54	O F F	626	50			22415	90
55	O F E	441	50			22059	29
56	O F F	144	00			13773	63
57	O F F	144	00			13773	63
58	O F F	685	50			14817	64
59	O F F	685	50			14817	64
60	O F F	5720	75			11029	61
61	O F F	5720	75			11029	01
52	B A C	944	64			44753	95
9	N. C	193	00			2782	08
14	N. C	825	00			1970	30
15	N. C	825	00			1970	30
30	N. C	710	00	71	56	3875	54
31	N. C	710	00			3875	54
32	H Q S	573	00			10152	06
36	N. C	UNKNOWN				80000	00
46	N. C	3909	50			7940	93
47	N. C	3909	50			7940	93
48	N. C	3913	16			7948	40
49	N. C	3913	16			7948	40
50	N. C	3418	88			6944	42
51	N. C	3418	88			6944	42
T-69	N. C	UNKNOWN				2400	00
T-70	N. C	UNKNOWN		107	02	2240	00
22	BAR	3424	90			47749	32
28	BAR	0063	09			80409	60
29	BAR	3747	09			76991	38
Total		3545	39	178	58	634265	89

3—8701

(5) Total Repair Expenditures from the Date the Building or System was Constructed to June 30, Present Fiscal Year		(6) Total Original Cost, not Including Repairs, to June 30, Present Fiscal Year		(7) Cost of New Construction (Including Alterations and Additions but not Repairs) During the Present Fiscal Year		(8) Replacement Value June 30, 19 39, Present Fiscal Year	
$ 17160	92	$ 48568	05	$		$ 98185	16
22617	07	48568	05			98185	16
14214	52	35403	00			70098	35
1156	62	5884	82			5884	82
261	73	5616	80			5616	80
317	85	5529	85			5529	85
310	95	5645	14			5645	14
299	57	5720	85			5720	85
35683	23	22425	23			51004	52
3469	80	7450	00			14758	92
298	93	8000	00			19600	00
11	97	UNKNOWN				800	00
3475	16	1450	00			3463	00
11	99	UNKNOWN				800	00
1714	83	2562	00			3974	58
535	24	1120	00			2770	24
690	95	565	69			1118	46
84	50	UNKNOWN				1000	00
6343	98	454	62			4400	00
478	37	957	00			2057	49
376	01	8253	00			16030	56
1	04	3190	00			6369	79
2	51	997	50			2154	93
5341	50	9932	62			21796	41
4	68	UNKNOWN				800	00
459	31	UNKNOWN				640	00
4626	36	21992	00			45796	14
337	71	400	00			400	00
469	61	1098	00			2230	25
10689	03	22702	00			43769	46
5683	41	20753	00			44812	75
9644	78	14529	29			27675	75
632	25	955	84			900	00
1016	89	3586	00			6913	81
2620	26	2846	00			3200	00
5061	59	UNKNOWN				3000	00
1737	01	6459	85			12400	00
685	03	47000	00			47988	00
367937	37	645161	59	178	58	1321757	08

3—8701

(1) Building No.	(2) Designation of B[uilding] or Syste[m]	(3) Original [Cost] Including [to] June 30, [Fi]scal Year		(7) Cost of New Construction (Including Alterations and Additions but not Repairs) During the Present Fiscal Year		(8) Replacement Value June 30, 1939, Present Fiscal Year	
80	STOREHOUSE	[5]000	00	$		$ 5020	00
81	E.M. GARAG[E]	[7]200	00			7228	00
82	GENRTR. HO[USE]	[11]500	00			11546	00
84	N.G. POST E[XCHANGE]	[U]NKNOWN				420	00
85	OFF. GARAG[E]	[U]NKNOWN				3200	00
88	GASOLINE T[ANK]	286	94			286	94
89	GARAGE	[2]000	00			2909	54
92	WAGON SCAL[E]	[1]350	00			1350	00
100	N.G. ADM. BL[DG]	[U]NKNOWN				2500	00
101	N.G. COMM[...]	[U]NKNOWN				2500	00
102	N.G. GUN S[HED]	[...]534	00			4200	00
103	N.G. MES[S]	[U]NKNOWN				2500	00
104	N.G. OFF.	[U]NKNOWN				2500	00
105	N.G. EM. L[...]	[U]NKNOWN				3000	00
106	N.G. MESS [...]	[U]NKNOWN				2500	00
107	N.G. MESS [...]	[U]NKNOWN				2500	00
108	N.G. MESS [...]	[U]NKNOWN				2500	00
109	N.G. MESS [...]	[U]NKNOWN				2500	00
110	N.G. MESS [...]	[U]NKNOWN				2500	00
111	N.G. MESS [...]	[U]NKNOWN				2500	00
112	N.G. MESS [...]	[U]NKNOWN				2500	00
113	N.G MESS H[...]	[U]NKNOWN				2500	00
114	N.G. MESS [...]	[U]NKNOWN				2500	00
115	N.G. MESS [...]	[U]NKNOWN				2500	00
126	SWIMMING P[OOL]	[...]000	00			2000	00
127	BLEACHERS	[1]200	00			1200	00
128	LILY POND	[...]000	00			3000	00
129	GARAGE	455	02			455	02
130	GARAGE	455	02			455	02
131	GARAGE	[4]55	02			455	02
132	GARAGE	455	02			455	02
133	GARAGE	[4]55	02			455	02
134	GREENHOUSE	[...]500	00			1500	00
136	W.D. THEATR[E]	[...]947	52			35000	00
139	BAND STAND	[...]400	00			400	00
140	N.G. MESS H[...]	[...]00	00			2500	00
141	TENNIS COUR[T]	[U]NKNOWN				1500	00
142	TENNIS COUR[T]	[U]NKNOWN				1500	00
143	TENNIS COUR[T]	[1]200	00			1200	00
144	TENNIS COUR[T]	[...]384	00			400	00
145	HANDBALL CO[URT]	[...]600	00			600	00
T-5	SENTRY BOX	[U]NKNOWN				100	00
T-7	VETERINARY	[U]NKNOWN				350	00
T-27	GAS TANK	[UN]KNOWN				350	00
T-33	WOOD SHED	[illegible]				[illegible]	00
T-12	TEAMSTERS Q[UARTERS]	[...]99	99			5128	07
Total		[...]37	92	178	58	145660	73

3—8701

M5260°—40 (Face p. 240) No. [...]

(4) ...nditures ...esent ...ear		(5) Total Repair Expenditures from the Date the Building or System was Constructed to June 30, Present Fiscal Year		(6) Total Original Cost, Not Including Repairs, to June 30, Present Fiscal Year		(7) Cost of New Construction (Including Alterations and Additions but not Repairs) During the Present Fiscal Year		(8) Replacement Value June 30, 19 39, Present Fiscal Year	
...98	35	$ 4122	74	$ UNKNOWN		$		$ 4000	00
...1	05	33	55	1700	00			1700	00
...57	48	263	61	5666	56			5666	56
...3	75	155	59	3512	70			3512	70
...25	60	185	17	UNKNOWN				3500	00
...11	76	163	11	3549	13			3549	13
...3	21	52	09	2299	10			2299	10
...1	60	8	90	153	48			400	00
		NONE		UNKNOWN				700	00
		NONE		100	00			100	00
		NONE		85	00			85	00
...19	15	948	98	UNKNOWN				675	00
...55	17	29469	30	UNKNOWN				15250	00
		651	39	UNKNOWN				6462	00
...37	60	10995	85	UNKNOWN				22500	00
...44	93	20202	89	UNKNOWN				242304	00
...57	14	4056	13	UNKNOWN				18750	00
...15	76	577	20	UNKNOWN				18750	00
...22	27	3937	88	UNKNOWN				3750	00
...54	10	3489	71	UNKNOWN				3750	00
...32	11	458846	87	742503	89	178	58	1795614	22

Howard H Reed

HOWARD H. REED, 1ST LT. (INF.) QMC FOR

(Signature) E. W. LACHMILLER, MAJOR, Q.M.C.

Quartermaster.

...o be forwarded to the Commanding General of the Corps Area, who will forward the original ...ll be forwarded as soon as possible after the close of the fiscal year. It will be noted that ...Corps Area have a copy of this information for all stations geographically located in his area. ...shown in the historical record on file in the Office of the Quartermaster General. Local

...eral's Office to determine within a reasonable degree how the annual repair funds have been ...: it is found necessary to paint the exterior woodwork, renew a part of the roof, replaster ...entry in column 3 would then appear as follows: Exterior painting $348, roofing $230, ...omitted as representative important repair items: Roofing, exterior painting, foundations,

...ding file under each individual building, in accordance with the procedure outlined in the ...fiscal year, the current fiscal year embraced by this report.
...ed over to the Quartermaster until the close of the present current fiscal year. If records ...l cost of repairs as recorded on the last fiscal year QMC 104.
...show the Quartermaster General and higher authority the actual cost of annual repairs in ...at hand, to make comparisons with the actual cost of construction and the probable cost ...ate detailed information for Congress in order to show, by actual examples, funds that are

...d 5 show only repair expenditures, columns 6 and 7 will show costs of original construction,

...rent fiscal year, each building structure and utility at all the stations in the Army. This ...y the help and assistance of local contractors. IT IS REQUESTED THAT SPECIAL ...T VALUE, NOT A FICTITIOUS ONE.
...tion and repair of buildings and utilities as is listed annually in the instructions on the ...ion to show: 1. Individual and separate Officers' Quarters, permanent; 2. Individual and ...5. Bachelor Officers' Quarters, permanent; 6. Bachelor Officers' quarters, temporary.

DEPARTMENT
Q.M.C. Form 205
Revised Sept. 21, 1935

PROJECT ESTIMATE

CONSTRUCTION AND REPAIR OF BUILDING AND UTILITIES

Reno Q. M. Depot, (Remount)

...ps Area 8th Station Fort Reno, Okla.

...f description of proposed project Electically-operated gasoline pump, purchase
... installation of.

...ing number - Original cost, $ - Replacement cost, $ -

...nt condition Two hand-operated pumps now in use are property of
...t Exchange. No Government-owned pump is on hand.

...iption and cost of major replacements made from date of completion to present date -

...l cost of repairs from date of completion to date, $ -

DETAILS OF PROPOSED PROJECT

(... include strength of garrison, present available accommodations, age of existing work, present condition, necessity for proposed work, details to ... type of construction, size, materials of construction, and detail estimate of cost. Sketches or plans and photographs should be attached ... applicable. Use extra blank sheets if required. Prepare sheet in triplicate.)

(Special attention must be given to Details. Nothing of value should be omitted.)

...is estimate covers the purchase and installation of one elec-
...ically-operated gasoline pump. There is at present no Govern-
...t-owned pump on hand. The two hand-operated pumps in use
... the property of the Post Exchange, are old and practically
...n out. Approximately 35,000 gals. of gasoline are issued and
...d in a year.

...uisition QM-731-35-40 for an electrically-operated gasoline
...p was submitted. There are attached a copy of requisition and
...y of letter from Quartermaster, 8th Corps Area, relative to
...ion on the requisition. Funds for the purchase of a gasoline
...p from Army Transportation allotment are not available at this
...tion. It is proposed that if funds are not available from the
...retary of War's reserve application be made by this office to
...artermaster, 8th Corps Area.

...t is particularly desired to obtain a new pump for installation
... connection with the installation of a 10,000-gal. underground
...oline storage tank, covered by a separate Project Estimate.
...timated cost is as itemized on reverse of this form.

...gs in {repairs / operation} of the sum of $ - will be made annually if this work is authorized.

...timated cost of material to be purchased	$ 327.50	Funds are available at the Post under P/A QM 3622 & 3749 A 999-0 for WPA labor in amount of $ 25.00
...lue of material on hand to be used	$	
...lue of regular post civilian labor to be used	$ 50.00	
...lue of enlisted labor (at 50 cents per hour) to be used	$	Funds are available at C. A. or Dept.
...timated cost of civilian labor ~~to be hired~~ W.P.A.	$ 25.00	Hdqtrs. under P/A
...timated cost of fuel, light, or power required	$	in amount of $
...tal estimated cost of project	$ 402.50	No funds are available. Allotment is requested in amount of
...timated cost if done by contract	$	$

...red under the direction of R. E. IRELAND, Major, Cav. (w/QMC),
Post Quartermaster.

...proved (date) December 9, 1939. Approved (date)

...L. DANIELS, Major, Q. M. Corps,
Post Commander. *C. A. or Dept. Commander.*

245260°—40 (Face p. 240) No. 4

			Material
1	ea.	Pump, gasoline, electrically-operated, computing type	$220.00
75	ft.	Pipe, wrought iron, galvanized, 2"	37.50
25	"	Pipe, wrought iron, galvanized, 2-1/2"	18.75
1	ea.	Cap, fill-up, 2", complete with lock	3.00
1	"	Cap, fill-up, 2-1/2", complete with lock	5.00
-	-	Pipe fittings	10.00
5	lb.	Litherage	.50
1	ea.	Valve, gate, brass, 2-1/2"	21.00
1	"	Valve, gate, brass, 2"	11.75
-	-	Labor, W. P. A.	
-	-	Labor, regular post	
			$327.50

(Face p. 240. Backs No. 4)

WAR DEPARTMENT
Q.M.C. Form 196 (old 509)
Revised July 2, 1934

WORK ORDER

MAINTENANCE OF UTILITIES

Order No. 262-40 {Building} No. 110

Requested by Lt. Hines Date 1/25/40

Date completed 2/10/40

Inspected and found satisfactory.

(Signed) "M", Capt., Q.M.C.

Nature of Order

Repaint all exterior woodwork.

Reputty sash where necessary.

Work assigned to

MR (Paint Shop)

Enlisted labor 80 hrs. @ 0.50 per hr.	$ 40	00
Civilian labor 40 hrs. @ 1.20 per hr.	48	00
Material: Purchased	50	20
Material: Stock on hand	2	75
Contracts		
Personnel, Project No. 1 40 hrs.	(No cost to be shown)	
Total cost	$ 140	95

Classification of repairs made: Perm. Off.

Project No. 12 Approp B. & QA. Designation Qrs.

NUMBER OF UNITS	UNIT	UNIT COST
1	B	140.95

(FOR DETAILS OF WORK SEE OTHER SIDE)

U.S. GOVERNMENT PRINTING OFFICE: 1934

AND LOCKERS

:RS		REMARKS
ig.	QUIN.	
23		
24		
25		
26		
28-B		
30		
31		
32		
41		
56		
57		
78		
33		
97		
51		
-J		
-J		

THIS SPACE FOR USE OF OFFICE QUARTERMASTER GENERAL TO RECORD SEMIANNUAL CORRECTION DATES

CHECKED	DATE

IDE)

15		2	14	12	12					
Sub-Total:										
Miscellaneous:										
8-F					8		7.10			
9	5	16		8	8		84.16			
14	1	11		8	8		54.78			
15				8						1
20 & 87	1 Civ	2		12	8		34.05			3
21		1								
28		1								
38		3								
39		1								
40		24		8	8		96.65			
42	2	12	(11Civ)	11	11					43
44		7		8-12	10-11		2.48		13.75	14
45										
46										
54	1	5	(3 Civ)	8	8		85.47			
54										
54										
55					8		.75			
56		2			8		1.40			
64										
83		1			8		1.42			
86	1	11	(1 Civ.)	8	8		69.10			
T-94				8			1.05			
97		7	(14 Civ)		8		8.50			
102		3	(3 Civ)		8		2.04			
105				8	8		2.18			
109							3.48			
114		6		8	8		73.32			
Sub-Total							527.91		13.75	67
Sales to individuals (B&A)									1.50	62
Sales to CMTC						X	11.68			
Street Lighting										
M.D. Technical Power										
SC " " "										
U.S. Lighthouse Service, Interdepartmental Transfer of funds										
" Coast Guard " " " " " " " " "										
" Weather Bureau " " " " " " " "										
Sales to Wright & Kremer										
Sales to Ross Engineering Co.										
Lighting and illumination - hand laterns.										
Motor driven fire apparatus										
Motor vehicles "AT-C"										
Sub-total							11.68		1.50	62
Grand Total							1461.65		424.00	365
APPENDIX:										
Chargeable to B&Q Funds: (Sub-total)							1449.97		422.70	30
" " " Other " " "							11.68		1.50	6
Grand Total							146165		424.00	36

* Blank column to be used as needed for charcoal (lbs.), steam (M ft.), coke (tons), kerosene (galls.), etc.

ELEC

Purch. rate, .012

Distrib. rate, .013

U. S. GOVERNMENT PRINTING OFFICE: 1922 3—9810

(Face p. 240. Backs No. 7)

Quartermaster School,
Schuylkill Arsenal,Phila., Pa.
Station January 3, 1940.

[H]EAT, LIGHT, AND POWER DISTRIBUTION

[On] hand [...], 1939	Received since July 1, 1939	Total to be accounted for Dec. 31, 1939	Consumed July 1 to Dec. 31, 1939	Balance on hand Dec. 31, 1939	Required balance fiscal year 1940	On contract, not yet delivered
[..].8	None	192.80	62.05	130.75	None	None
[..].54	1787.71	2283.25	1813.61	469.64	4400	As called fo r.
0	496.4	496.4	496.4	0	600.00	"
0	55471	55471	55471	0	64000	"
0	18489	18489	18489	0	21300	"
[..]68	4215	4283	3991	292	5500	"

[...]l (pounds), steam (M feet), coke (tons), kerosene (gallons), etc.

L. I. Cobb

L.I. COBB, Major, Q.M. Corps,
Quartermaster.

[...]ear.

U. S. GOVERNMENT PRINTING OFFICE 3—10095

WAR DEPARTMENT
M. C. Form No. 109
Revised Dec. 14, 1928

.41 Date June 30, 1937.

. 15

STACK

UNIT NO.	THICKNESS	DAMPER CONTROL	MATERIAL	DIA.	HEIGHT	DATE ERECTED
1	U.S.S. #10	Spence	Radial Brick	7'6"	125'	1933
2	"	"				
3	"	"				

S OR OIL BURNERS

UNIT NO.		SHOP NO.	H. P.	DRIVEN BY—	DATE INSTALLED
1		1744	253 ±	Engine	1933
2		1745	"	"	"
3		1743	501 ±	"	"

ED-DRAFT FANS

UNIT NO.		SHOP NO.	ST. PR.	C. P. M.	R. P. M.	DRIVEN BY—
1	e	2358890			1860	~~Turbine~~ Motor
2		2353889	6"	21000	1400	Turbine
3						
4						
5						

STEAM TURBINES

UNIT NO.	UFACTURER	TYPE	STEAM INLET	EXHAUST	H. P.	R. P. M.
1		BFB	2"	3"	15	3500
2		"	"	"	15	3500
3		"	"	"	"	

June 30, 1937.

PLANT

Steam Inlet	Steam Exhaust	Operates Vacuum Pumps
2"	3"	One
2"	3"	Two
2"	3"	Three

245260°—40 (F

N BUILDING NO. 15

S.	WASTE	STEAM-FLOW METERS				
		UNIT NO.	NAME OF MANUFACTURER	CAT. NO.	STEAM MEAS'D per hr	PIPE NOZZ
	15%	1	Brown	2021	15000	3.3
		2	"	"	"	"
		3	"	"	30000	5.3

d of measuring coal Movable coal scale

d of measuring boiler feed water Cochrane Lea V Notch

d of measuring ash none

ion of the boiler feed water Good with Chemical treatment

h plans of boiler and engine room showing layout.

available, make sketch of same in space below.

INSTRUCTIONS

r inspector in making
s officer on his records

izontal tubular, inter-
oilers of the Kewanee
n square feet of radi-

er for heating or to
ers. Engines: State
perate saw mill, run

draft fans are driven;
er of operating engine
orm No. 90.
pressure in inches of
per minute.
c., give sizes of pipe

Remarks.—If boilers, engines, or other apparatus are transferred f
another post, state where they came from and age at time installed.

This form is for permanent record and will be used only when
installations are made, or extensive alterations or additions are first c
pleted and turned over for use.

Forms will be prepared in triplicate. One copy of each form wil
retained at the station where prepared, one copy will be forwarde
the Department or Corps Area Commander, and one copy (the origi
will be forwarded to the Quartermaster General. At independent
tions forms will be prepared only in duplicate, one copy for retentio
the station, and the other for submission to the Quartermaster Gene

Slight modifications, alterations, or additions will be reported promp
upon completion of the work to the Quartermaster General, as direc
in par. 7, AR 30–1770.

3–

DEPARTMENT
C. Form No. 110 (Old 514)
...ed Dec. 3, 1920

At ...ate June 30th, 1935

...GLES

PLANT NO.	N...	NO. ROLLS	LNG.	STEAM	DRIP	TRAP Inlet	TRAP Outlet	TRAP Name of—
20		4	110"	1½"	1"	1½"	1"	Armstrong

...IRONERS

PLANT NO.	N...	NO. ROLLS	LNG.	STEAM	DRIP	TRAP Inlet	TRAP Outlet	TRAP Name of—
22	W...	1	66"	½"	½"	½"	½"	Crane
23								

...SSES

PLANT NO.	N...	STEAM	DRIP	CAP. Lbs.	TRAP Inlet	TRAP Outlet	TRAP Name of—
		1/2"	1/2"	100	1/2"	1/2"	Armstrong
		1/2"	1/2"	100	1/2"	1/2"	"
		1/2"	1/2"	100	1/2"	1/2"	"
		1/2"	1/2"	100	1/2"	1/2"	"

...ERS

PLANT NO.	N...	...M	DRIP	R. P. M.	TRAP Inlet	TRAP Outlet	TRAP Name of—
		1"	1"	26	3/4"	3/4"	Troy.

...CENTRIFUGALS

PLANT NO.	N...	...o.	DIA.	R. P. M.	D. PLG.	BELT.	SHOP NO.
1							
2			28"	1100	3"	4"	113102-63
3							
4							
5							

...HERS

PLANT NO.	N...		DIA.	LNG.	STEAM	W. PR.	DRN.	SHOP NO.
6								
7								
8								
9								
10			36"	36"	1½"	60	6	113102-51
11			36"	54"	1½"	60	8	113102-41
12			42"	72"	1½"	60	10	113102-31
13								

...AND STORAGE TANKS

PLANT NO.	N...	...M	DRIP	STEAM PR.	C. W.	H. W.	STORAGE CAPACITY	CAPACITY PER HOUR
14								
15								
16								
17			2"	125	3"	2"	500	1500
18								
19								
20								

245260°—40 (Face p.

INUED

LIST OF MISCELLANEOUS EQUIPMENT

OF MACHINE	TYPE	NO.	NAME OF MANUFACTURER
ks.			
kers	Steam	1	Troy Laundry, Inc.
	60 Gal.Galv.St	2	Troy Laundry, Inc.
tubs	Granitine	1	Troy Laundry, Inc.
ss			
ers			
press			
ner	Steam	2	Huebash
ner			
ble			
bles	Stationary	4	Troy Laundry, Inc.

EET FOR LAUNDRY PLANT

"W. P.," working pressure. Type all brackets or suspension hanging,

If the G. P M. are not known, give der, diameter of water cylinder, and

r of each machine, 24-25-26, or 24-26 es of the same size.

Name of trap—Fisher, Kieley, More-

n, drip, cold water, and hot water are that the heating will raise from 60°

ated" put the plant number of the

mber of machines of the same kind.

ite numbers at least three-fourths of nit in reports.

permanent record. When this shall ne post or station; the other two (2) Headquarters, one copy to be retained master General.

alterations, and additions will be re- f the work.

U. S. GOVERNMENT PRINTING OFFICE: 1927

WAR DEPARTME
Q. M. C. Form No. 111 (Old
Revised October 23, 1

NGS

Date June 30, 1939 Reservation—Area 1366 acres.

Name Fort Hancock d 1366 acres. Leased None acres.

Character of post Coast da, New Jersey

Capacity: Off. 27 Marr 6 Bach veh. 15 Govt 67 Pvt. ; Hosp. beds 50 Beds 15 Attdts.

POST BLDG. No.	DESIGNATIO BUILDIN	Storm Windows	Screens	CAPACITY	REMARKS ON CONDITION OF BUILDINGS
	PERMANENT				
53	Post Excha		26	5153' 5153'	Good, cap. includes basement
60	Post Excha				
	Service St			1214' 1214'	Very Good
94	Post Excha				
	& Tailor S		11	14cars 2cars	Fair (Pvt. Cars)
	PERMANENT				
109	Post Child				
	School	10	17	4219' 4219'	Good
	OTHER PER				
70	Gymnasium		7	3902' 7695'	Good, cap. includes basement
91	Tennis Cou			7980' 7980'	Good
93	Tennis Cou			11447' 11447'	Good
95	Theatre		7	398Pers. 398Pers.	Good
112	N.C.O. Club	16	29	2990' 2990' 1NCO 1NCO	Good
113	Caddy Hous		2	353½' 353½'	Good
114	Officers C			3marr. Off.	3married Off.
	Officers C	56	79	85208' 85208'	Good
	OTHER TEM				
T-45	Recreation		18	200Pers.	Good
T-75	E.M. Bath H		12	100Pers. 100Pers.	Poor
T-86	Officers B				
	Club		36	1630.9 Ft	Good
	PERMANENT				
33	Q.M. Bake S		15	500# 500#	Good
	RESERVATI				
89	Fence			344' 344'	Good
	FLAGSTAFF				
78	Flagstaff			100' 100'	Good
	PERMANENT				
22	Barracks		60	109EM 109EM	Fair-Artillery Barrack
23	Barracks	17	84	109EM 109EM	Fair-Artillery Barrack
24	Barracks	2	62	109EM 109EM	Fair-Artillery Barrack
25	Barracks	1	53	109EM 109EM	Fair-Artillery Barrack
74	Double Art				
	Barracks	34	134	218EM 218EM	Fair-Artillery Barrack
102	Barracks	53	111	94EM 94EM	Fair-Artillery Barrack
	TEMPORARY				
T-46	Dormitory		29	40 Pers.	Good-Formerly CCC Building
T-47	Dormitory		30	40 Pers.	Good-Formerly CCC Building
T-48	Dormitory		30	40 Pers.	Good-Formerly CCC Building
T-49	Dormitory		30	40 Pers.	Good-Formerly CCC Building

U. S. GOVERNMENT PRINTING OFFICE 3—9033

245260°—40 (Fac

DITION OF BUILDINGS

SHEET #2

DATE June 30, 1939

Kitchen Sinks	Washbasins	Laundry Tubs	Shower Baths	Bathtubs	Fire Extinguishers	Fire Buckets	Storm Windows	Screens	Designed Capacity	Present Occupancy	Remarks on Condition of Buildings
								30	40 Pers.		Good-Formerly (
1	3	3		2	1	1	20	50	1 Lt.	1 Capt.	Good
1	3	3		2	1	1	9	48	1 Lt.	1 Capt.	Good
1	3	4	1	2	1	4	11	50	1 Lt.	1 Capt.	Good
1	3	3		2	1	1	20	45	1 Lt.	1 Lt.	Good
1	3	3		2	1	4	16	53	1 Lt.	1 Lt.	Good
1	3	3	1	2	1	2	14	49	1 Lt.		Good
1	3	2		2	1	2	14	26	1 Lt.		Good
1	3	3		2	1	3	17	49	1 Lt.		Good
1	4	3		3	1	5	17	49	1 Capt.		Good
1	4	3	1	3	1	6	22	50	1 Capt.	1 Maj.	Good
1	4	3		3	1	4	25	50	1 Capt.	1 Maj.	Good
1	4	3		3	1	4	29	77	1 Mtd.Off.	1 Col.	Good
1	4	3	1	3	1		12	44	1 Capt.	1 Capt.	Good
1	4	3		3	1		24	62	1 Capt.	1 Lt.Co	Good
1	4	3	1	3	1	1	22	49	1 Capt.	1 Lt.Co	Good
1	4	3		3	1	1	10	49	1 Lt.	1 Capt.	Good
1	3	3		2	1	1	18	49	1 Lt.	1 Capt.	Good
1	3	3	1	2	1	1	13	49	1 Lt.	1 Lt.Col.	Good
2	3	2	2	3				46	2 Off.	1 Lt. 1 Capt.	Excellent
2	3	2	2	3				46	2 Off.	2 Lt.	Excellent
2	3	2	2	3				53	2 Off.	1 Lt. 1 Capt.	Excellent
1	8	2	3	7	3		21	43	6 Off.	6 Off.	Good
	4		2					22	6 Pers.		Good
1	2	1		2	1	1	21	28	1 NCO.	1 NCO	Fair
2	2	2		2	2		14	28	2 NCO.	2 NCO	Good
1	1			1	1		7	9	1 Fam.	1 Fam.	Good
1	1	1		1	1		7	9	1 Fam.	1 Fam.	Fair
2	2	1		2	2		17	23	2 Fam.	2 Fam.	Fair
2	2	3		2	2		8	27	2 Fam.	2 Fam.	Fair
1	1			1	1			30	1 Fam.	1 Fam.	Fair
2	2	2		2	2		15	22	2 Fam.	2 Fam.	Good
3	3	6		3	3		10		3 Fam.	3 Fam.	Good

buildings at the post available for the purpose indicated.
building indicated.
of ranges.
for the preparation of Historical Records, Form 117 (Old Form 173 a).

RECEIVED AUG

3—9095

DEPARTMENT
Form No. 112
Dec. 27, 1928

TIES

At Fort L[e] June 30, 1939.

POST NAME OF STREET OR ROAD	ION	EXTENSIONS OR ALTERATIONS			
		KIND	DIAM.	LENGTH	REMARKS
Air Field Road					
Augur Ave.	od	C.I.	6"	916'	Theatre
Bluntville Rd.					
Buford Ave.					
Cantonment Rd.					
Custer Ave.					
Gibbon Ave.	od	Vit.Clay	4"	200'	Theatre
Grant Ave.	od	"	6"	100'	"
	od	"	8"	305'	"
Kearney Ave.					
McClellan Ave.					
	od	Vit.Clay	6"	247'	Theatre
McDowell Ave.					
McPherson Ave.					
"					
"	od	W.I.	2"	280'	Bldg.224
"		W.I.	2"	120'	" 254
Meade Ave.		W.I.	2"	700'	" 128
Meigs Ave.		W.I.	2"	354'	" 27
Sherman Ave.		W.I.	1"	200'	" 85

Organ Ave.	
Piggery Roads	LTERATIONS, OR REPLACEMENTS IN EQUIPMENT
Pope Ave.	
Hunt Lodge	
Quarry No. 2	dditions, alterations or replace-
" 3	nts in equipment.
Reynolds Ave.	
Riverside	
" Ser.Ro	
Scott Ave.	
Sedgwick Ave.	
Sheridan Drive	
Sherman Ave.	
Stockade	
Sumner Place	ansformer, 25 K.V.A. Gen.Elec.,2400
Thomas Ave.	ary voltage,60 cy.,1-phase,120-240
Upton Ave.	ndary voltage; Type H60, installed
Wint Ave.	ar Dept. Theatre,Bldg.27, Aug. 1938.
Biddle Blvd.	condition.
Girl Scout Road	
Water Plant "	report "Electric Lighting & Power,"
Bluntville Lane	C. Form #90 for additions.)
Bluntville Loop	
Old Elec.Shop Road	
Cemetery Road	
Riley Ave.	

DITION OF UTILITIES

Date June 30, 1939.

VERNMENT OWNED		RAILROAD OWNED		TOTAL TURNOUTS	TOTAL MILES TRACK
S TRACK	TURNOUTS	MILES TRACK	TURNOUTS		
	12	5.8	4	16	14.644
		3.28	3	3	3.28
		.91	1	1	.91

EPTH OF EAN LOW WATER	DIFFICULTIES IN MAINTAINING AND REPAIRING WHARF	REPAIRS MADE	
		KIND	DATE

'es GOVERNMENT OWNED Yes LEASED

UTTS	TRENCH		FACILITIES
LENGTH	WIDTH	HOW DRAINED	
550'	10'	Ditch	Water connections None
			Sewer connections None
			Telephone Yes
			Electric lights None

IN BLDG. No.	CONDITION	ADDITIONS, ALTERATIONS, OR REPLACEMENTS IN EQUIPMENT
		None
S) 27	Good	-1 new Richmond Heatomat Gas fired boiler, Type 89SC, Se Cap. 6975 sq. ft.
185-B	"	1 new gas fired boiler, Gen.Elec., Type 21-IM-26A1-800
272-A	"	1 new Kewanee #1736, 680 sq.ft.
38-A	"	1 new gas fired boiler, Gen.Elec., Type 21IM-26A1, 680
128	"	1 new Killam Burner for Boiler.

pment of the utility referred to during the present fiscal year will be reported. Opposite have been no additions or alterations statement to that effect will be made.

3—9600

DEPARTMENT
Form No. 113 (Old 518)
Dec. 1, 1921

At Date June 30, 1939

AGITATORS

PLANT NO.	URER	TYPE	DIA. PROPELLER	WIDTH BELT	R. P. M.	DRIVEN BY—	SERIAL NO.
1	o.	C.I.	20"	4"	90	Motor	No
2	o.	C.I.	20"	4"	90		No.

AMMONIA CONDENSERS

PLANT NO.	URER	TYPE	NO. OF PIPES	LENGTH PIPES	SIZE	TOTAL LENGTH OF PIPE
1	o.	shell 18'		long 16in. diameter		
2	s	refg. per		24 hours	245	sq. ft.
1						
	o.	Vertical,		shell tube		

AMMONIA RECEIVER

PLANT NO.	
	Ammonia Receiver
1	15.1 Cu. Ft.
2	
1	
2	
1	
1	

OIL SEPARATOR

TYPE	
	urge and drain valves
F	
F	
Bl	
Bl	
Bl	
Bl	

ICE-HARVESTING EQUIPMENT

TYPE	
	e 39 ton
	nes, capacity 300 lb.
	raise cans from tanks

REMARKS

BRINE OR D.E.	
Brine	
"	
"	
"	

̇OR REFRIGERATING PLANTS

le-acting " V. S. A.," or horizontal
ıe plate.
single or double belt, as " 8″–S " or

ɔund by multiplying the area of the
ıy the number of R. P. M. times the

s to be inserted the plant number of

brine or circulating water, etc.
of the motor driving the pump.
ıspheric," etc., " T. I. A." The total
er.
" Switch for motor " insert the plant

of the tank. Under the " Coil " give
coil, " T. ft." The capacity of ice
," " Storage," etc.
.d height of the room. " Purpose,"
ə ratio is the number of cubic feet to

ərmit. Under " Remarks " add any

:e numbers at least three-fourths of
; in reports.
permanent record. When this shall
ə post or station; the other two (2)
eadquarters, one copy to be retained
ıaster General.
ations, and additions will be reported
rk.

GOVERNMENT PRINTING OFFICE

WAR DEPARTMENT
Q. M. C. Form No. 114
Approved Apr. 2, 1931

At FORT WAY JUNE 30, 1939

Name of contractor T "B" CAPACITY

Point of delivery POS ETER WORKS," BALTIMORE.

COMPANY

Size of incoming mains ITY GAS COMPANY

High-pressure governor {Q N BUILDING NO. 73

Nature of gas N

CTOR

Material	Dia.	(F	Depth laid	Protective coating	Date installed
IRON	$1\frac{1}{4}$"	6	$3\frac{1}{2}$'	'BITUSDAMASC'	July1912
IRON	$1\frac{1}{2}$"	11			
STEEL	$1\frac{1}{2}$"				
IRON	$1\frac{1}{2}$"	1			
IRON	2"	12			
IRON	2"	6			
IRON	3"	4			
IRON	4"	2			
IRON	4"	31			
	Total,				

This form is for permanent r ains, with location of drips and valves. Indicate by symbol turned over for use. h laid. (Distance from top of pipe to surface of ground.)
Forms will be prepared in trip using gas.
will be forwarded to the Departmen shown by placing an asterisk in the column headed "Size."
Quartermaster General. At indepe imum where there are marked fluctuations in the pressure.
station and the original will be for data pertaining to each separately.
Slight modifications, alteration ces, group together by brackets or otherwise indicate those
ticulars with notation to be made as "Barber Co.," etc.
such slight modifications, etc. Ina No. 3," etc.
hereon will be considered accurate a 4 burners, etc.

3—9952

245260°—40 Face p. 2

APPARATUS

3—0052

...LLED IN BUILDING	SERVICE CONNECTION		HEATING BOILER		HOT WATER HEATER, NAME AND SIZE	COOKING RANG...	
Designation	Size	Pressure	Name of Boiler	Name of Burner		Name	Numb... burn...
Offcrs' Qtrs.	* 2"	3"-5"	-	-	Hot Zone #3	Norge	5
Offcrs'Apt.Hse	* 2"	3"-5"	-	-	----------	--------	----
Offcrs' Apt.	* $1\frac{1}{2}$"	3"-5"	-	-	- - -	Norge	5
" "	* $1\frac{1}{2}$"	3"-5"	-	-	- - -	Norge	5
" "	* $1\frac{1}{2}$"	3"-5"	-	-	- - -	Norge	5
" "	* $1\frac{1}{2}$"	3"-5"	-	-	- - -	Norge	5
NCO Qtrs.	* $1\frac{1}{4}$"	3"-5"	-	-	Keystone.300	Norge	5
" "	* $1\frac{1}{4}$"	3"-5"	-	-	" "	Norge	5
" "	* $1\frac{1}{4}$"	3"-5"	-	-	" "	Garland	5
" "	* $1\frac{1}{4}$"	3"-5"	-	-	" "	Norge	5
" "	*$1\frac{1}{4}$"	3"-5"	-	-	" "	Detroit	5
" "	* $1\frac{1}{4}$"	3"-5"	-	-	" "	Norge	5

** Qtrs. #8 Now used as Officers' Mess has been provided with two similar ranges.

*** Building No. 66 under renovation----activities temporarily in Building No. 76.

This space for use of O. Q. M. G. to record semiannual correction dates

CHECKED	DATE

U. S. GOVERNMENT PRINTING OFFICE

WAR DEPARTMENT
Q. M. C. Form No. 115 (Old 519-
Approved Dec. 1, 1921

At Patterson Fiel Date February 3, 1939.

BLDG. NO.	D	REMARKS
1	Depot Wareh	
2	Paint, Oil	
5	Depot Garag	
7	Gymnasium	
8	Officers' Q	
11	Headquarter	
13	Engineering	installed 9-9-39 Cost $27.05
	High Pressu	
16	Officers' Q	
26	Disassembly	
28	Final Assem	
30	Oil Reclama	
46	Stock Room	
47	Paint Shop	
49-A	Gasoline &	
50	Utilities S	
52	Dope House	
54	Engineering	lled 1-13-40-
65	Q. M. Wareh	
66-A	Propeller	
73	Quarters,	
74	"	
75	"	
76	"	
87	"	
114	Gasoline S	
145	Steel Hang	
163	Fire Stati	
168	Q. M. Maint	
169	Q. M. Gara	
63-A	Water Pump	
	To	
13	Engineer	12, 1940. Cost $89.72

245260°—40 (Face p.

CENTRAL HEATING PLANTS

mber of central heating plant from

ve plant number of engine as shown

ermanent record. When this shall
post or station; the other two (2)
adquarters, one copy to be retained
aster General.
tions, and additions will be reported
k.

3—9640

WAR DEPARTMENT
Q. M. C. Form No. 116 (Old Fo
Approved Dec. 1, 1921
Revised Feb. 5, 1925

At Patterson Fi February 3, 1939.

BUILDINGS		HEATERS, FURNACES, AND FIREPLACES							
		ROOM HEATERS, DIAMETER					FURNACES		FIRE-FLACES
POST NUMBER	DESIGNATIO	18"	20"	22"	24"	26"	No.	Diameter Grate	No.
15	Post Hospita								
88	Officers' Qu								
110	Radio Statio								
121	Operations O								
301	Officers' Qu								
303	"								
304	"	ants in the building.							
309	"								
311	"								
316	"	lants.							
319	"								
321	"								
323	"								
325	"								
327	"								
329	"								
330	"								
332	"								
401	"								
403	"								
405	"								
407	"								
409	"								
411	"								
416	"								
418	"								
420	"								
422	"								
424	"								
430	"								
432	"								
501	"								
503	"								
505	"								
507	"								
511	"								
516	"								
518	"								
520	"								
522	"								
524	"								
530	"								
532	"								
601	"								
603	"								

245260°—40 (Face p.

PLANTS

3—0639 *Date* February 3, 1939

LER	HEATED BY STOVES, ROOM HEATERS, FURNACES, AND FIREPLACES														
	STOVES, DIAMETER GRATE						ROOM HEATERS, DIAMETER						FURNACES		FIRE-FLACES
y Sq. der's ng	7"	9"	10"	12"	14"	16"	16"	18"	20"	22"	24"	26"	No.	Diameter Grate	No.
40	(Double Set)														
30															
30															
40	(Double Set)														
30															
30															
30															
30															
30															
30															
40	(Double Set)														
40	(Double Set)														
20															
00	(Double Set)														
20															
40	(Double Set)														
40	("		"	)											
30															
30															
70															
00	(Double Set)														
20															
30															
30															
40	(Double Set)														
30															
30															
				1											
				2											
				2											
				4											
				3											

the size, as the
, etc. Capacity

e different size
e designated in
ree stoves with
16". This also
the diameters

es, whether one
d be given.
ill be reported
master General,
lding concerned
ect the heating
a new Form 520

This space for use of O. Q. M. G. to record semiannual correction dates

CHECKED	DATE

AR DEPARTMENT
M. C. Form No. 116 (Old Form 300)
Approved Dec. 1, 1921
Revised Feb. 5, 1926

At Patterson Field, February 3, 1939

HEATERS, FURNACES, AND FIREPLACES

BUILDINGS		ROOM HEATERS, DIAMETER					FURNACES		FIRE-PLACES
POST NUMBER	DESIGNATION	18"	20"	22"	24"	26"	No.	Diameter Grate	No.
	N. C. O. Quarters								
	" "				1				
	Hangar 12	1			2				
	" 9				4				
	" 8				2				
	" 6								
	" 5				1				
					1				
	Hangar 4				1				
	" 3				1				
	" 1								
	Civilian Quarters								
	Sewage Pump House								
	Salvage Shop								
	Gate Guard House								
	Test Block								
	Harling Hangar								
	Main Gate								
	Guard House								
34	Warehouses								

air, 5400 CFM, air delivery
motor, Made by The Trane
umbers 5305, 5306,5307,
39, 53040.

NG PLANTS

3—0630 *Date*______________________________

	HEATED BY STOVES, ROOM HEATERS, FURNACES, AND FIREPLACES														
N BOILER	STOVES, DIAMETER GRATE						ROOM HEATERS, DIAMETER						FURNACES		FIRE FLAC
apacity Sq. t. Builder's Rating	7"	9"	10"	12"	14"	16"	16"	18"	20"	22"	24"	26"	No.	Diameter Grate	No

;ing the size, as the 36–6", etc. Capacity

of the different size ould be designated in re three stoves with the 16". This also n are the diameters

urnaces, whether one should be given.
ns will be reported artermaster General, building concerned ll affect the heating use a new Form 520

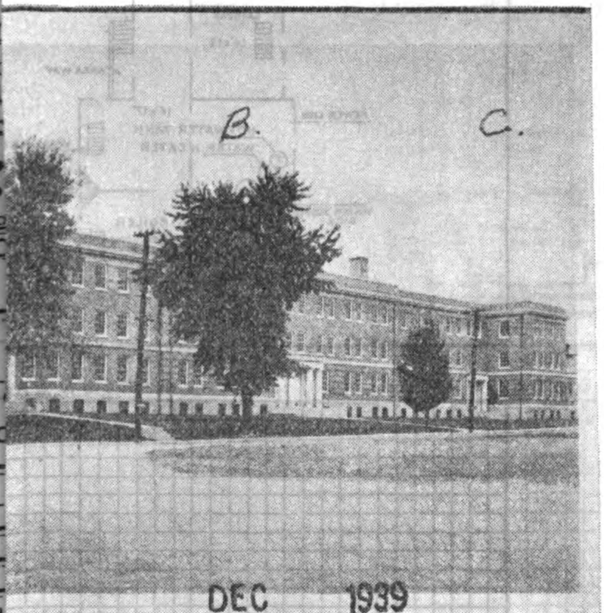
o8

This space for use of O. Q. M. G. to record semiannual correction dates

CHECKED	DATE

ARTMENT
rm No. 117 (Old No. 173A
. 21, 1924

700 **Building No.** 64 A,B & C.



Place ......Fort T
Designation of build
Total cost, $ 521,1
Material: Walls Br
Roof Concrete,
Total floor area abo
Size: Main building
a C
b Hot Water -
c Steam coil

COO

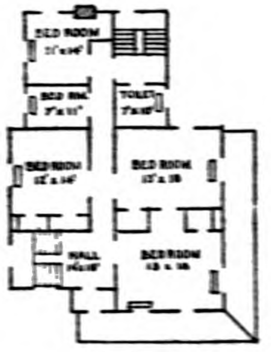
Coal, No. ----
Gas, No. 6
Electric No. ----
Oil, No. ----
Steam, No. ----
Constructed und
600.1 C-NB(Ft.

DATE			COST
10-6-39	F		

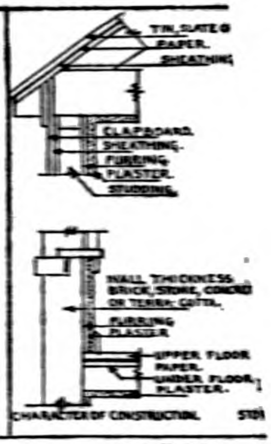
fireplaces.

See reverse side c

245260°—40 (Face p. 240) N



SECOND FLOOR



DETAIL

VING DATA AS PER PLANS ABOVE

NS

be checked against the building and any variations from same in the building as constructed sho

quarters." Similar plans may be made for all types of buildings. There are 10 squares to the in
inside dimensions and designation of each room. Indicate location of water and sewer connectio

How much of the above storage is in daily use .....

	Total Purchased, 1,000 Gallons	Cost		Tot. Treat...
1st				273
2d				
Total				
Av. Purchased Rate				Av. P

20

[1] Sum of costs U. S. plants, boosting, treating, and purchases.

EQUIPME

No.	Class of Equipment	Manufacturer
2	Pumping engines (Motor driven)	Liberty
1	Chemical ~~hose~~ trucks (Motor driven)	Chevrole
	Hook and ladder trucks (Motor driven)	
1	Utilities cars (Motor driven)	Ford, A
7	Wheel type chemical extinguishers	
	Hose cart—hand drawn	
620	1-quart extinguishers	
1723	2½-gal. soda extinguishers	
49	2½-gal. foam extinguishers	
	5-gallon hand pumps	
10175 Ft.	Hose, 2½" double jacketed	
	Hose, 2½" single jacketed	
2662 Ft.	Hose, unlined linen	
300 Ft.	" Cotton fiber	1½"

REMA

As to suitability of fire-fighting equipment; wr
required, and what prevention measures have been
As to fire hazards existing. Hazards that hav

Conditions as a whole are g
to constitute fire hazards

(Face p. 240. Backs No. 19)

Total plant
Average unit
Average unit
Average cost
Condition of

Total popul

Military pop

Average num

U. S. GOVERNM

245260°—

gal.

...d Furnished or ...d by U. S. Plant, ...000 Gallons	Cost		Total Distributed, 1,000 Gallons	Average Rate Per 1,000 Gallons Distributed Water	Total Cost of Distributed Water	
613	9406	55	267773	.036	9803	61
...lant Rate			Av. Distr'b'd Rate			

...NT IN SERVICE AND RESERVE

...s Name, Number, and Rating	In Service		In Reserve		Surplus	
	No.	Condition	No.	Condition	No.	Condition
Class B	2	Excellent				
t., M. 1934	1	Good				
	1	Fair				
	7	Fair				
	620	Good				
	1723	"				
	49	"				
	9875	Good	300	Excellent		
	1962	Good	700	Excellent		
	300	"				

...RKS AND RECOMMENDATIONS

...ter pressure and supply; efficiency of personnel; whether additional equipment is ... taken.
... been eliminated. Hazards still existing and how these hazards can be overcome.

3—10335

...ood, but temporary structures continue
... No remedy except complete reconstruction.

Plant repairs, enlisted lab
Plant repairs, civilian
Plant repairs, materials
Minor repair cost
Major repair cost
TOTAL PLANT COST

Total plant output
Average unit cost produc
Average unit cost distrib
Average cost in adjoining
Condition of plant

Total population

Military population

Average number of anim

U. S. GOVERNMENT PRINTING OFFICE

0°—40 (Face p. 240)

Maximum pressure on system
Minimum pressure on system
Storage capacity
Storage capacity
How much of the above storage is 20

	Total Purchased, 1,000 Gallons	
1st		
2d		
Total		
Av. PURCHASED RATE		

[1] Sum of costs U. S. plants, boosting, trea

No.	Class of Equipment	
2	Pumping engines (Motor driven)	
1	Chemical hose trucks (Motor driven)	
	Hook and ladder trucks (Motor driven)	
1	Utilities cars (Motor driven)	
14	Wheel type chemical extinguishers	
	Hose cart—hand drawn	
49	1-~~quart~~ Gal. extinguishers	
1628	2½-gal. soda extinguishers	
	2½-gal. foam extinguishers	
	5-gallon hand pumps	
7500 ft.	Hose, 2½" double jacketed	
	~~Hose, 2½" single jacketed~~	
3806 ft.	Hose, unlined linen	
32	1 qt. Pyrene Exts.	

As to suitability of fire-fightin required, and what prevention me
As to fire hazards existing. E

Fire fighting equipm
Due to large quantity c
and large amount of che
is a real need for a mo
ciency of personnel exa

Only known fire haz
eliminated.

(Face p. 240. Backs No. 20

lb. head ... ft.

200,000 gal. for fire protection.

1,400,000 gal. for domestic use.

daily use ... All ... gal.

Cost	Total Furnished or Treated by U. S. Plant, 1,000 Gallons	Cost		Total Distributed, 1,000 Gallons	Average Rate Per 1,000 Gallons Distributed Water	Total Cost of Distributed Water	
	273613	9406	55	267773	.036	9803	61
	233499	9592	93	228421	.044	10106	23
	507112	18999	48	496194		19909	84
	Av. Plant Rate	9499	74	Av. Distr'b'd Rate		9954	92

ting, and purchases.

EQUIPMENT IN SERVICE AND RESERVE

Manufacturer's Name, Number, and Rating	In Service No.	In Service Condition	In Reserve No.	In Reserve Condition	Surplus No.	Surplus Condition
Liberty, Class B	2	Excellent				
Chevrolet, M. 1934	1	Fair				
rord A	1	Poor				
	14	Excellent				
	49	Good				
	1698	"				
	7500	Good				
NOTE: Differences in fig-	3886	Good				

ures shown hereon from last report caused by recedpt of ew equipment or the disposal of old equipment.

REMARKS AND RECOMMENDATIONS

g equipment; water pressure and supply; efficiency of personnel; whether additional equipment is asures have been taken.

azards that have been eliminated. Hazards still existing and how these hazards can be overcome.

3—10335

ent adequate except for fighting gasoline and chemical fires.
f gasoline handled and stored for vehicles, tanks and airplanes
micals at Army Field Printing Plant and Reproduction Plant, there
dern chemical truck. Water pressure and supplies adequate, effi-
ellent.

rds consist of temporary buildings which are gradually being

)

MA

RTMENT
No. 17 (Old Form No. 90)

REPORT OF BOILER INSPECTION

10
11

Boiler inspected at Schuylkill Arsenal, Date December 26, 1939.

Type of boiler {water tube / fire tube}, or Water Tube (3) Manufactured by Franklin Boiler Co.

Manufacturer's number of boiler - (5) Plant number of boiler 3 (6) Date installed 1907

Rated capacity - H. P. (8) {Portable or Stationary} Stationary (9) {Number of boilers in battery} 3

State the general condition of the setting Good

State service of boiler (lighting, pumping, sawmill, fortification, etc.) Heating

Does boiler contain {grease or scale} Scale? (13) If so, is the quantity of same serious? No (14) Does boiler show signs of pitting or corrosion? Yes

If so, to what extent? Slight

What change in boiler feed water is recommended? None

Does boiler show sign of bags or blisters? No (18) If so, what repairs are necessary?

-

What hydrostatic pressure was applied to the boiler? 114 lbs. (20) Did boiler show signs of under this pressure? No (21) If so, where and to what extent? -

Is this the maximum hydrostatic pressure that can be applied? Yes (23) If not, why was er pressure applied? Pressure applied in proportion to working pressure.

State maximum safe working pressure, 76 lbs., and manufacturer's rated pressure, Not known lbs.

State number, length, and size of tubes in boiler 115 - 16' x 3½"

Are all tubes tight? Yes (27) If not, how many leak? - (28) How many can be ht by rolling or calking? - (29) How many new tubes are required? -

How many safety valves are installed on this boiler? One (31) State the Lonergan Type Spring Pop Size 4"

State the condition of each To be set under steam.

At what pressure were safety valves set to open? - lbs. (34) At what pressure did safety valves - lbs. (NOTE: Where two safety valves are installed, it is desired that they be set to open at ately 5 lbs. difference in pressure.)

What variation in pressure existed between boiler pressure gauge and test gauge at working pressure? calibrated (36) Was gauge corrected? No

What is condition of water column and try cocks? Good

What is condition of fusible plug? Not required

What is condition of blow-off? Good

What apparatus is provided for feeding the boiler? 3 H. D. Pumps 6" x 4" x 6" and 1 Electric.

(41) What is the general condition of the boiler feeding apparatus and boiler feed piping? Good

(42) What additions or repairs, if any, are cons necessary to boiler feeding apparatus?

(NOTE.—Where additional space is required for answers to above questions, replies are to be recorded following space. Each reply to be headed by question number. Under item No. 24, where tensile stren steel and type of rivet holes are not known, strength of boiler shall be calculated for steel with tensile stren 60,000 lbs. per square inch and rivet holes punched full size.)

(43) REMARKS AND RECOMMENDATIONS by the Inspector:

Applied hydrostatic pressure of 114 lbs. per sq. inch to boiler. Same shows no signs of weakness or defects under hydrostatic pressure. Examination sho slight scale in generator tubes and steam drum shows slight pitting but not active Brick work in good condition.

Recommend safety valves to be set under steam at 76 lbs. per sq. inch.

D. G. Smith
(Signature of Inspector)

Assistant Inspector of Boilers.
(Official title of Inspector)

(44) REMARKS AND RECOMMENDATIONS by the local Officer in Charge: Office of the Quartermas Quartermaster School, Philadelphia, Pa. Dec. 29

In accordance with recommendations of the inspector; Scale in generator t has been removed.

Arrangements have been made for gauge to be calibrated.

Safety Valve will be set under steam of 76 lbs. when boiler is again place in operation.

L. L. Cobb
(Signature of Officer in Charge)
L. L. COBB,
Major, Q.M. Corps,
Quartermaster.
(Official title of Officer in Charge)

3—6021

(Face p. 240. Backs No. 21)

DELIVERY ORDER AND RECEIPT

Delivery Order No. 352

Work Order No. 2531-40

. Dix
(Post, camp, or station)

12/1, 1939
(Date)

to ________ the following supplies.
(Name of individual organization)

For Bldg. No. 232
(Building No., shop, plant, or system)

Delivered	Stock No.	Articles	Unit	Space for Accounting: Unit Cost	Space for Accounting: Total Cost	
15	52-P-1356	Inside cream paint	Gal	1.20	18	00

cles listed in column "Delivered" have been received. 12/2 1939

Smith, Foreman Painter
(Name) (Rank)

Q.M.C.
(Organization)

aken By Jones	Issued By Jones	Posted By Hogan
12/1	Date 12/2	Date 12/21

DUPLICATE

GPO 3—4881

5260°—40 (Face p. 240) No. 22

CREDIT MEMORANDUM

Credit Memo. No. 221

Not used on Work Order No. 2531-40

t. Dix ... 12/20, 1939
(Post, camp, or station) (Date)

he following supplies have been returned to ... (Warehouse
aint Shop
of shop)

NT NED	ARTICLES Stock No.		UNIT	SPACE FOR ACCOUNTING Unit Cost	Total Cost	
	52-P-1356	Inside Cream Paint	Gal.	1.20	2	40

ls listed in column "Amount Returned" have been received 12/23, 1939

ohn Smith, Foreman Painter Q.M.C.
(Name) (Rank) (Organization)

ln by	Posted to work order by	Taken up in shop stock	Posted to stock records by
rner	Daly	Smith	Oliver
	Date 12/20	Date 12/20	Date 12/28

.C. Form No. 446
oved January 29, 1936
-12059

ORIGINAL

245260°—40 (Face p. 240) No. 28

Appendix II

CALCULATION OF FUEL AND LIGHT ALLOWANCES

1. A method of calculating fuel and light allowances for a noncommissioned officer's quarters in accordance with AR 30-1620 and AR 30-1625 follows:

a. Situation.—(1) Quarters No. 208 at Fort School, Pa., occupied by Technical Sergeant S, Q. M. C. (married), are heated by hot water. There are 720 square feet of equivalent direct radiation in that building. The table of hours of operation (par. 5*a*(1)), AR 30-1620) is as follows:

	Hours
October	110
November	220
December	450
January	450
February	420
March	220
April	85
All other months	0

(2) The fuel used for heating buildings at that post was fuel oil. Artificial gas was supplied for cooking and for heating water for domestic use. Electricity was used for mechanical refrigeration and for lighting. The authorized wattage for that set of quarters is 760 watts.

(3) Technical Sergeant S, Q. M. C., has been at Fort School from July 1, 1938, to January 31, 1939, and during that period actually has consumed—

1,920 gallons of fuel oil costing $0.05 per gallon.

37,125 cubic feet of artificial gas, costing $0.90 per M (1,000 cubic feet), for cooking and for domestic hot water.

1,020 kilowatt-hours of electricity, costing $0.015 per kilowatt-hour, for mechanical refrigeration and lighting.

b. Requirement.—The monetary status of the fuel and light account of Technical Sergeant S, Q. M. C., for heating his quarters,

245260°—40——16

and for cooking, heating water for domestic use, lighting, and mechanical refrigeration, as of January 31, 1939.

c. Solution.—(1) *For heating building* (par. 5*a*(2)(*b*), AR 30-1620).

720 square feet = Equivalent direct hot-water radiation.
1,230 hours = Number of hours of operation (par. 5*a*(1), AR 30–1620).
0.0272 lb. = Standard fuel per hour per square foot of direct radiation.

Therefore, Technical Sergeant S's allowance for heating his quarters from July 1, 1938, to January 31, 1939, was—

$$720 \times 0.0272 \times 1{,}230 = 24{,}088 \text{ pounds of standard fuel.}$$

From the table in paragraph 6*c*(1)(*b*), AR 30–1620, it is found that the fuel oil actually issued to Technical Sergeant S had a conversion factor of 12.00. Therefore, his allowance in terms of the fuel actually issued was—

$$\frac{24{,}088}{12} = 2{,}007.3 \text{ gallons of fuel oil.}$$

Technical Sergeant S consumed only 1,920 gallons of fuel oil. Therefore, he had a fuel saving of—

$$2{,}007.3 - 1{,}920 = 87.3 \text{ gallons of fuel oil.}$$

(2) *For cooking and domestic hot water* (par. 5*b*(2), AR 30-1620).—(*a*) For cooking for the period July 1, 1938, to January 31, 1939, he was entitled to 750 pounds of standard fuel per month or $7 \times 750 = 5{,}250$ pounds of standard fuel. From the table in paragraph 6*c*(1)(*b*), AR 30–1620, we find that the conversion factor from standard fuel to artificial gas for cooking is 0.40. Therefore, his cooking allowance in terms of artificial gas was—

$$\frac{5{,}250}{0.40} = 13{,}125 \text{ cubic feet of artificial gas.}$$

(*b*) For domestic hot water for the period July 1, 1938, to January 31, 1939, he was entitled to 750 pounds of standard fuel per month or $7 \times 750 = 5{,}250$ pounds of standard fuel. From the table in paragraph 6*c*(1)(*b*), AR 30–1620, the conversion factor for heating water is 0.25. Therefore, his allowance in terms of artificial gas was—

$$\frac{5{,}250}{0.25} = 21{,}000 \text{ cubic feet of artificial gas.}$$

Technical Sergeant S had a total allowance of $13{,}125 + 21{,}000 = 34{,}125$ cubic feet of artificial gas, and as he consumed 37,125 cubic

feet he had an excess consumption of 37,125 − 34,125 = 3,000 cubic feet = 3M cubic feet of gas.

(3) *Electricity for mechanical refrigeration and lighting.*—(*a*) *For mechanical refrigeration* (par. 5*b*(2)(*c*), AR 30–1620).—For this item, the allowance is 300 pounds of standard fuel per month or 7 × 300 = 2,100 pounds of standard fuel for the period July 1, 1938, to January 31, 1939. From the table in paragraph 6*c*(1)(*b*), AR 30–1620, we find that the conversion factor from standard fuel to electricity for mechanical refrigeration is 5.00. Therefore, Technical Sergeant S's allowance of electricity for mechanical refrigeration was—

$$\frac{2{,}100}{5} = 420 \text{ kilowatt hours per year.}$$

(*b*) *Electricity for lighting* (par. 8*a*, AR 30–1620).—The authorized wattage for that set of quarters is 760 watts, and each lamp is authorized 500 hours. Therefore, his annual allowance of electricity for lighting was—

$$760 \times 500 = 380{,}000 \text{ watt hours} = 380 \text{ kilowatt hours.}$$

His allowance for lighting for the period July 1, 1938, to January 31, 1939, was (by par. 8*e*(2), AR 30–1620)—

July, August, and September =
3 months at $6\frac{1}{3}$ percent = 19 percent

October, November, December, and January =
4 months at $10\frac{1}{3}$ percent = $41\frac{1}{3}$ percent
$19 + 41\frac{1}{3} = 60\frac{1}{3}$ percent

$380 \times 60\frac{1}{3}$ percent = 229.3 kilowatt hours.

Technical Sergeant S, Q. M. C., had a total allowance of 420 + 229.3 = 649.3 kilowatt hours of electricity, and as he consumed 1,020 kilowatt hours of electricity he had an *excess* consumption of 1,020 − 649.3 = 370.7 kilowatt hours.

(4) *Summary.*—The fuel and light account of Technical Sergeant S, Q. M. C., as of January 31, 1939, was as follows:

Item	Unit	Quantity	Unit cost	Saving	Excess
Heating building	Gallons, oil	87.3	.05	$4.365	
Cooking and domestic hot water.	M cubic feet, gas	3.0	.90		$2.70
Lighting and mechanical refrigeration.	Kilowatt-hours, electricity.	370.7	.015		5.56
Total				4.365	8.26

Technical Sergeant S, Q. M. C., exceeded his allowance by—

$8.26—$4.36=$3.90

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[A. G. 062.11 (5–27–40).]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:
E. S. ADAMS,
Major General,
The Adjutant General.

U. S. GOVERNMENT PRINTING OFFICE: 1940

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